Section 11 Geology and Soils

This section discusses geologic and seismologic conditions and soil resources in the study area, along with associated potential geologic, seismic, and geotechnical hazards. This section describes the associated study area, the environmental setting, the significance of potential environmental impacts, and potential mitigation measures.

The Delta Plan (the Proposed Project) does not propose implementation any particular physical project; rather it seeks to influence, either through limited policy regulation or through recommendations, other agencies to take certain actions that will lead to achieving the dual goals of Delta ecosystem protection and water supply reliability. Those actions, if taken, could lead to physical changes in the environment. These potential actions are described in more detail in part 2.1 of Section 2A, Proposed Project and Alternatives, and in Section 2B, Introduction to Resource Sections.

Construction and operational impacts would be associated with water supply reliability, ecosystem restoration, water quality improvement, flood risk reduction, and enhancement actions primarily in the Delta and in the Delta watershed and to a lesser extent in areas outside the Delta that use Delta water. The types of impacts related to geology, geologic hazards, and soils include those related to construction on known earthquake faults, and unstable geologic units; construction of fill slopes, which can have impacts related to landslide potential in levee slope areas; construction on soils susceptible to liquefaction hazards, expansive soils, and soils that have high organic contents; the potential for soil erosion; the potential for soil shrinking and swelling; and the potential for construction of on-site wastewater disposal in inadequate soils.

Impacts would be potentially significant, but could be reduced to less than significant when feasible mitigation measures can be implemented. The Delta Stewardship Council does not have the authority to require the adoption of mitigation in all cases. Therefore, some construction activities conducted by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), may not be mitigated to a less-than-significant level. This section evaluates and discloses the significance of geologic impacts before and after the implementation of mitigation measures.

11.1 Study Area

The study area is defined as the geographical area in which the majority of potential geologic are expected to occur. The study area for geology and soils consists of the legal Delta and Suisun Marsh, the Delta watershed, and areas outside of the Delta that use Delta water. As described in Section 2A, Proposed Project and Alternatives, facilities could be constructed, modified, or reoperated in the Delta, Delta watershed, or areas located outside the Delta that use Delta water. It is unclear where these facilities would be located. While it is unclear where the Delta Plan and the Delta Plan alternatives will have effects outside the Delta, this section discusses the general types of effects on geology and soils that might occur in the Delta watershed and areas outside the Delta that use Delta water.

11.2 Regulatory Framework

Appendix D provides an overview of the plans, policies, and regulations relating to geology within the study area.

11.3 Environmental Setting (Geology)

This section describes the geologic characteristics within the study area that could contribute to potential impacts as a result of adopting the Delta Plan or implementing the alternatives. The discussion focuses primarily on the geology and geologic hazards within the Delta and Suisun Marsh, because the Delta Plan policies and recommendations would likely have the greatest impact within the Delta. However, it is recognized that actions affecting geology and geologic hazards could be undertaken in areas outside the Delta and a general discussion of the geology in other areas is provided.

Consideration of seismic risk involves not only the Delta, but the surrounding region, which may affect the Delta. Active faults not proximal to the project area can affect it by generating seismic shaking. The region considered herein for evaluation of seismic risk extends up to 30 miles from the Delta, incorporating potentially causative faults.

11.3.1 Major Sources of Information

The information on geology provided in this section is based on existing information from published sources, including maps and reports prepared by the California Department of Water Resources (DWR), such as the Delta Risk Management Strategy (DRMS) Technical Memorandum (DWR 2007a), and maps and reports prepared by the CALFED Bay-Delta Program (CALFED), the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), and the California Geological Survey (CGS). Other sources include unpublished consulting reports.

11.3.2 Delta and Suisun Marsh

This section describes the existing geologic and seismologic conditions and the associated potential geologic, seismic, and geotechnical hazards in the Delta and Suisun Marsh area. The geologic setting focuses on the surficial soils and the underlying bedrock units, including the existing levee and channel deposits. Soils resources are fully discussed in Section 11, Geology and Soils, and Section 13, Mineral Resources, of this Environmental Impact Report (EIR). The seismologic setting describes historical seismic events and the ground-shaking potential during earthquakes. Geologic and seismic hazards, including surface fault rupture, seismically induced liquefaction, and slope instability and ground failure, are identified. Potential levee instability and breaches related to geologic processes that could result in flooding are also described. See Section 3, Water Resources, for a full discussion of levee stability.

11.3.2.1 Geologic Setting

The Delta and Suisun Marsh lie within California’s Central Valley, which is approximately 465 miles long and 40 to 60 miles wide. The Central Valley is bounded by the Sierra Nevada Range on the east and by the Coast Ranges on the west. The historical Sacramento–San Joaquin Delta is a flat-lying river delta that evolved at the inland margin of the San Francisco Bay Estuary as two overlapping and coalescing geomorphic units: the Sacramento River Delta to the north and the San Joaquin River Delta to the south. The Sacramento River Delta comprises about 30 percent of the total Delta area and was influenced by the interaction of rising sea level and river floods that created channels, natural levees, and marsh plains. During large river-flood events, silts and sands were deposited adjacent to the river channel, forming natural levees above the marsh plain. In contrast, the larger San Joaquin River Delta—having relatively small flood flows and low sediment supply—formed as an extensive, unleveed freshwater tidal marsh dominated by tidal flows and organic (peat) accretion (Atwater and Belknap 1980). In the past, because the San Joaquin River Delta had less well-defined levees, sediments were deposited more uniformly across the floodplain during high water, creating an extensive tule marsh with many small, branching tributary channels. Because of the differential amounts of inorganic sediment supply, the peat of the San Joaquin River Delta grades northward into peaty mud and mud toward the natural levees and flood basins of the Sacramento River Delta (Atwater and Belknap 1980).

Paleogeographic reconstructions of this region indicate that in Miocene time, from approximately 23.0 to 5.3 million years ago (mya), the area where the Delta exists today was a shallow, offshore marine depression situated between a seaward subduction zone and an associated landward volcanic arc. This setting resulted in shedding of arkosic quartz, feldspar and mica sands, and volcaniclastic deposits westward from the continent into the depression. From approximately 5.0 to 3.0 mya, during the Pliocene epoch, a shift in plate tectonics triggered uplift of the Coast Ranges, which gradually closed the southern marine outlet to the basin (Jones et al. 2004). In that time, subaerial (dry land) conditions prevailed throughout the valley that resulted from marine regression (a decrease in sea level) and sedimentation from the west. During Pleistocene time (approximately 2.6 to 11,400 mya), the Great Valley (known also as the Central Valley) separated from the Pacific Ocean and developed internal drainage. The modern outlet through the Carquinez Strait to the San Francisco Bay developed in middle Pleistocene time, around 1.3 mya (Lettis and Unruh 1991 and Figure 11-1).

The Delta is a northwest-trending structural basin, separating the primarily granitic rock of the Sierra Nevada from the primarily Franciscan Formation rock of the California Coastal Range (Converse Ward Davis Dixon 1981). The basin is filled with an approximate 3- to 6-mile-thick layer of sediments deposited by streams originating in the Sierra Nevada, Coast Ranges, and South Cascade Range that eventually discharge into San Francisco Bay.

The Delta received thick accumulations of sediments from the Sierra Nevada to the east and from the Coast Ranges to the west beginning in Cretaceous time and continuing to the present. The Delta has experienced several cycles of deposition, nondeposition, and erosion that have resulted in the accumulation of thick, poorly consolidated to unconsolidated sediments overlying the Cretaceous and Tertiary formations since late Quaternary time. Shlemon and Begg (1975) believe that the peats and organic soils in the Delta began to form about 11,000 years ago during an episode of sea level rise. This rise created tule marshes that covered most of the Delta. Peat and other organic soils formed from repeated burial of the tules and other marsh vegetation.

As the Suisun Marsh formed, plant detritus slowly accumulated, compressing the saturated underlying base material. Mineral sediments were added to the organic material by tidal action and during floods. Generally, mineral deposition decreased with distance from the sloughs and channels (Miller et al. 1975). Suisun Marsh soils are termed “hydric” because they formed under natural tidal marsh conditions of almost constant saturation. The soils adjacent to the sloughs are mineral soils with less than 15 percent organic matter; although classed as “poorly drained,” the mineral soils are better drained than the more organic soils in the marsh.

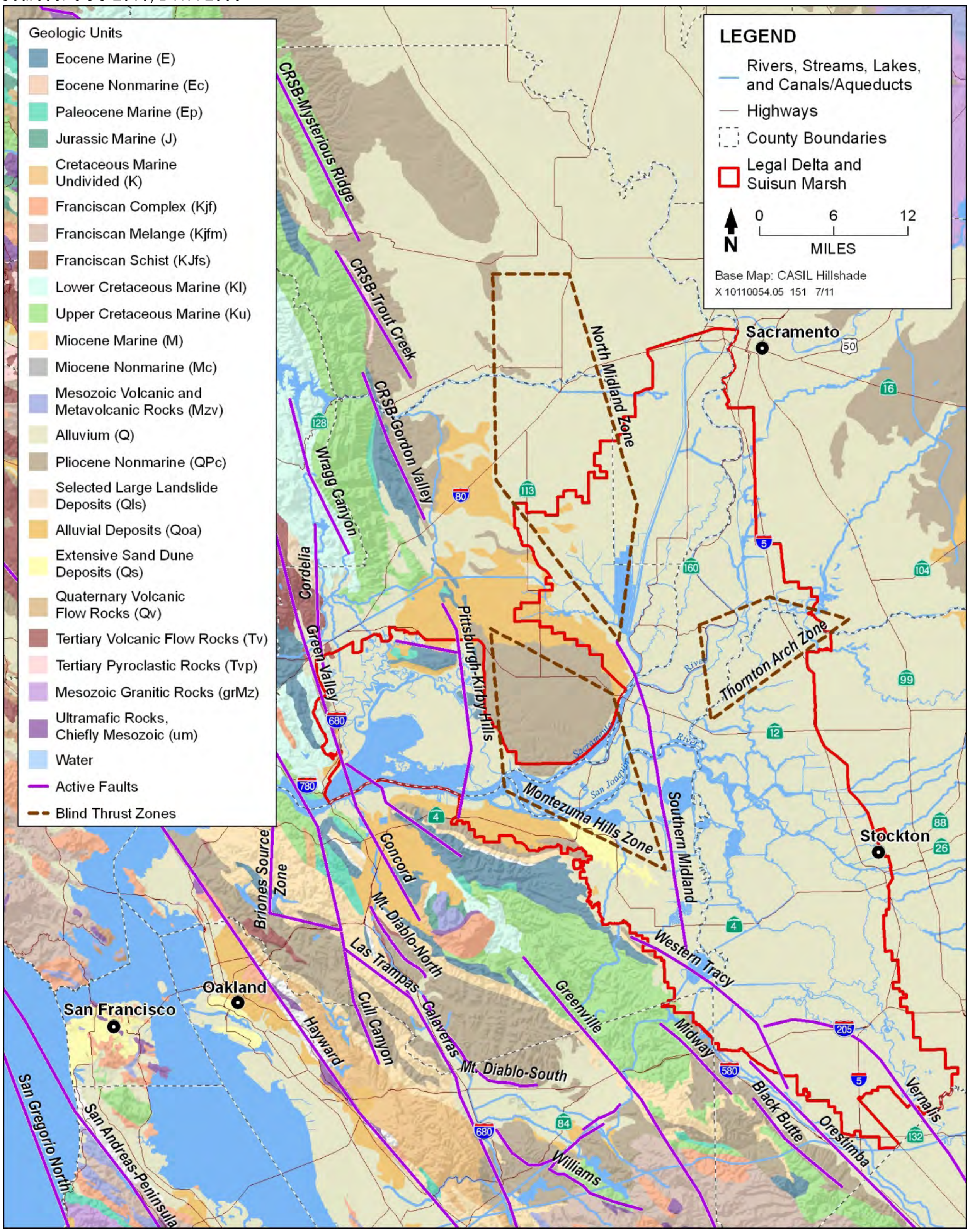
Suisun Marsh soils occur far from the sloughs, at the lowest elevations, and have over 50 percent organic matter content. Another common soil in the Suisun Marsh is the Valdez series, which formed on alluvial fans and contains very low amounts of organic material. Valdez series soils are found primarily on Grizzly Island (Miller et al. 1975).

The Suisun Marsh is bordered by upland soils that are nonhydric and contain very little organic material. The Suisun Marsh was originally formed by the deposition of silt particles from floodwaters of Suisun Slough, Montezuma Slough, and the Sacramento–San Joaquin River network. The top layer in the Suisun Marsh area is mainly peat and organic soils, generally called “young bay mud,” which is underlain by sand aquifer.

Figure 11-1

Regional Geologic Map (Portion of the 2010 State Geologic Map of California)

Sources: CGS 2010; DWR 2008



The natural surface geologic units over the Delta and Suisun Marsh include peat and organic soils, alluvium, levee and channel deposits, dune sand deposits, older alluvium, and bedrock.

11.3.2.1.1 Peat and Organic Soils

The tule marshes created by rising sea levels beginning approximately 11,000 years ago covered most of the Delta and led to the formation of peat and other organic soils, which is shown on Figure 11-2 and described in Table 11-1. The thickness of organic soils and peat in the Delta generally ranges from about 55 feet near Sherman Island to almost nonexistent toward the southern part of the Delta (Real and Knudsen 2009). The Suisun Marsh area is generally underlain by thick organic soils and peat, which are more than 40 feet thick in some places near the bay (Graymer et al. 2002).

11.3.2.1.2 Alluvium

Alluvium is soil or sediment deposited by a river or other running water and is typically composed of a variety of materials, including fine particles of silt and clay and larger particles of sand and gravel. A river continually picks up and drops solid particles of rock and soil from its bed throughout its length. Where river flow is fast, more particles are picked up than dropped. Where the river flow is slow, more particles are dropped than picked up. Areas where more particles are dropped are called alluvial plains or floodplains, and the dropped particles are called alluvium. Even small streams make alluvial deposits, but it is in the floodplains and deltas of large rivers where large, geologically significant alluvial deposits are found. The mapped alluvial deposits found in the Delta (Figure 11-2) are described in Table 11-2.

11.3.2.1.3 Levee and Channel Deposits

The ability of a river to carry sediments varies greatly with its flow volume and velocity. When a river floods over its banks, the water spreads out, slows down, and deposits its load of sediment. Over time, the river's banks are built up above the level of the rest of the floodplain. The resulting ridges are called natural levees. When the river is not flooding, it may deposit material within its channel. Artificial or constructed levees are built to prevent flooding of lands along the river; these confine flow, resulting in higher and faster water flow than would occur naturally. Artificial levees control sedimentation in the modern Delta. Natural and artificial levee deposits have been mapped (Figure 11-2) and are described in Table 11-3 (Graymer et al. 2002).

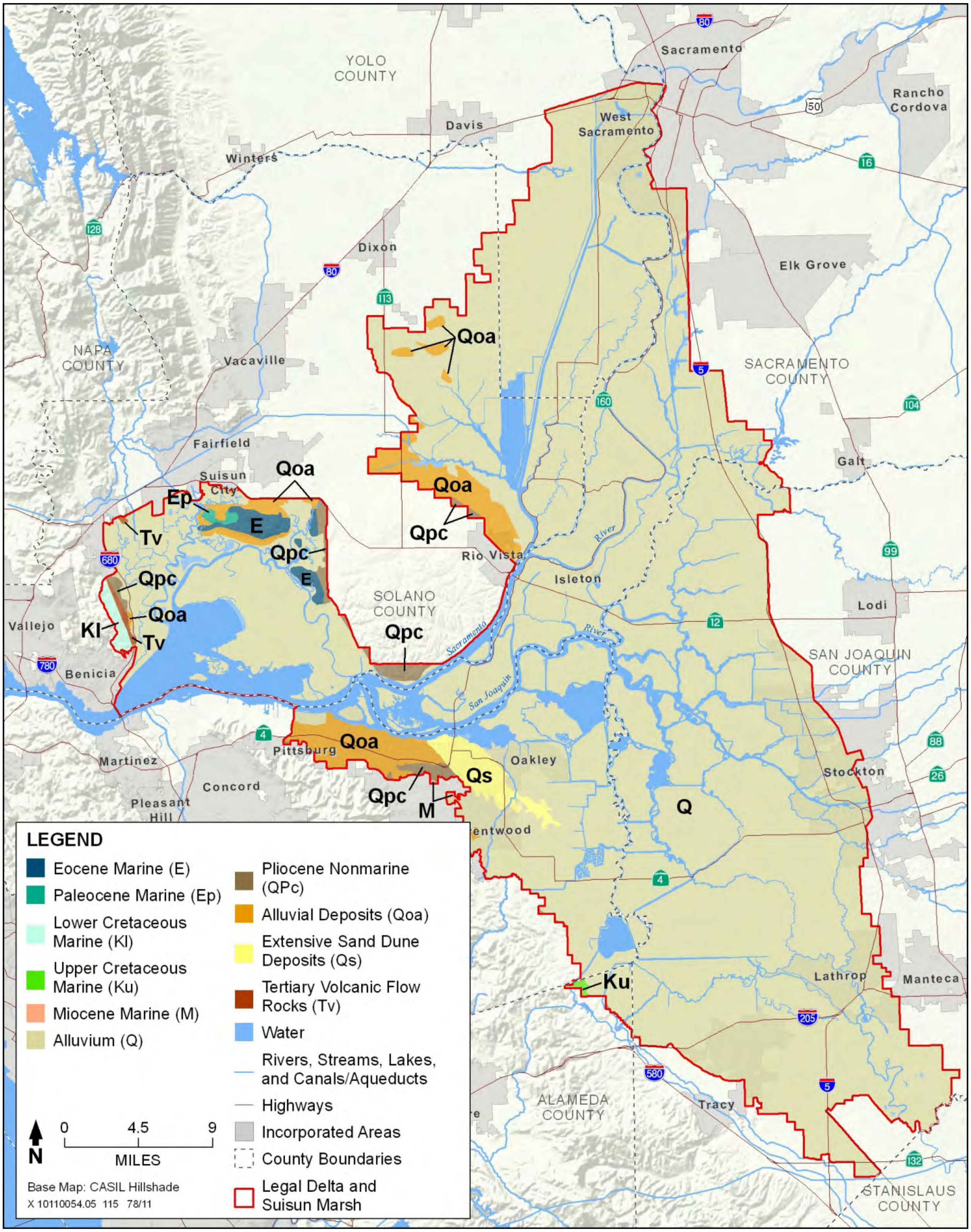
11.3.2.1.4 Dune Sand Deposits

Dune sand deposits consist of very well sorted fine- to medium-grained eolian (wind-deposited) sand. Holocene sands may discontinuously overlie the latest Pleistocene sands, both of which may form a mantle of varying thicknesses over older materials (Figure 11-2). Most of the deposits are thought to be associated with the latest Pleistocene to early Holocene periods of low sea level, during which large volumes of fluvial and glacially derived sediments were blown into the dunes (Atwater 1982). Dune sand deposits are described in Table 11-4.

11.3.2.1.5 Older Alluvium

The older alluvium consists of the Pleistocene-aged Modesto and Riverbank formations, which were deposited during separate episodes of glacial outwash derived from the glaciated core of the Sierra Nevada. This was interpreted by Marchand and Cherven from observations of upward coarsening within the units (Lettis and Unruh 1991; Marchand 1977; Cherven and Graham 1983).

1 Figure 11-2
2 Geologic Units in the Suisun Marsh and Delta
3 *Source: CGS 2010*



4

1 Table 11-1
2 Mapped Peaty Mud

Deposit	Map Unit	Descriptions
Bay Mud	Qhbm	Water-saturated estuarine mud (predominantly gray, green, blue, and black), clay, and silty clay underlie the marshlands and tidal mud flats of San Francisco Bay and Carquinez Strait. The mud also contains lenses of well-sorted fine sand and silt, a few shelly layers (oysters), and peat. The mud inter-fingers with, and grades into, fine-grained fan deposits at the distal edge of Holocene fans. This unit is time-transgressive and generally occupies the area between the modern shoreline and the historical limits of tidal marsh.
Delta Mud	Qhdm	Mud and peat with minor silt and sand are deposited at or near sea level in the Delta. Much of the area underlain by this unit is now dry because of dike and levee construction and is below sea level because of compaction and deflation of now-unsaturated Delta sediments.

Source: Graymer et al. 2002

3

Table 11-2
Mapped Alluvium

Deposit	Map Unit	Descriptions
Younger Alluvium	Qhay	Loose sand, gravel, silt, and clay deposited in active depositional environments and judged to be less than 1,000 years old, based on geomorphic expression or historical records of deposition.
Alluvium	Qha	Sand, silt, and gravel deposited in fan, valley fill, terrace, or basin environments and mostly undissected by later erosion. Typically mapped in smooth, flat, valley bottoms in medium-sized drainages and other areas where geomorphic expression is insufficient to allow differentiation of depositional environment.
Terrace	Qht	Moderately well-sorted sand, silt, gravel, and minor clay deposited in point bar and overbank settings. These deposits are as much as 32.8 feet (10 meters) above the historical floodplain but are mostly undissected by later erosion.
Alluvial Fan	Qhf	Moderately to poorly sorted and moderately to poorly bedded sand, gravel, silt, and clay deposited where streams emanate from upland regions onto more gently sloping valley floors or plains. Holocene alluvial fan deposits are mostly undissected by later erosion. In places, Holocene deposits may form only a thin layer over Pleistocene and older deposits.
Fine-grained Alluvial Fan	Qhff	Mostly silt and clay with interbedded lenses of sand and minor gravel deposited at the distal margin of large alluvial fan complexes.
Alluvium	Qa	Sand, silt, and gravel deposited in fan, valley fill, terrace, or basin environments. Similar to unit Qha, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time. In Yolo County, this unit includes the Modesto and Riverbank formations (Helley and Barker 1979).
Terrace	Qt	Moderately to well-sorted, moderately to well-bedded sand, gravel, silt, and minor clay deposited on relatively flat, undissected stream terraces. Similar to unit Qht, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time.
Alluvial Fan	Qf	Poorly sorted, moderately to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. Similar to unit Qhf, this unit is mapped where deposition may have occurred in either Holocene or late Pleistocene time.

Table 11-2
Mapped Alluvium

Deposit	Map Unit	Descriptions
Alluvium	Qpa	Poorly to moderately sorted sand, silt, and gravel in the Capay area (Esparto quadrangle). This unit is mapped on gently sloping to level alluvial fan or terrace surfaces where separate fan, terrace, and basin deposits could not be delineated. Late Pleistocene age is indicated by depth of stream incision, development of alfisols, and lack of historical flooding.
Alluvial Fan Deposits	Qpf	Poorly sorted, moderately to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. Late Pleistocene age is indicated by erosional dissection and development of alfisols. These deposits are about 10 percent denser and have 50 percent greater penetration resistance than unit Qhf (Clahan et al. 2000).
Basin Deposits	Qpb	As mapped by Atwater, older alluvium widely but sparsely exposed at the toe of the Putah Creek fan (Dozier quadrangle), most commonly in basins between stream-built ridges of younger alluvium (Atwater 1982).
Pediment Deposits	Qop	Thin deposits of sand, silt, clay, and gravel on broad, planar erosional surfaces. These deposits are extremely dissected, have well-developed soils, and are mostly tens or hundreds of meters above the current depositional surface.
Alluvium	Qoa	Sand, silt, clay, and gravel deposits with little or none of the original geomorphic expression preserved. Moderately to extremely dissected, in places tens or hundreds of meters above the current depositional surface, and capped by well-developed soils. In Yolo County, this unit includes the Red Bluff Formation as mapped by Helley and Barker (1979).

Source: Graymer et al. 2002

Note: Geologic units are listed in order of age (youngest to oldest).

Table 11-3
Mapped Levee and Channel Deposits

Deposit	Map Unit	Descriptions
Artificial Channel	Ac	Modified stream channels, usually where streams have been straightened and realigned. Deposits in artificial channels range from concrete in-lined channels to unconsolidated sand and gravel deposits similar to those that occur in natural stream channels (Qhc).
Artificial Levee Fill	Alf	Constructed deposit of various materials and ages, forming artificial levees as high as 20 feet (6.5 meters). Some are compacted and quite firm, but fills made before 1965 are generally uncompacted and consist simply of dumped materials. Levees bordering waterways of the Delta, mudflats, and large streams were first constructed as long as 150 years ago. The distribution of artificial levees conforms to the levees shown on the most recent USGS 7.5-minute quadrangle maps.
Stream Channel	Qhc	Loose sand, gravel, and cobbles with minor clay and silt deposited within active, natural stream channels.
Natural Levee	Qhl	Moderately to well-sorted sand with some silt and clay deposited by streams that overtop their banks during flooding. Natural levees are often identified by their low, channel-parallel ridge geomorphology.
Floodplain	Qhfp	Medium- to dark-gray, dense, sandy to silty clay. Lenses of coarser materials (silt, sand, and pebbles) may be locally present. Floodplain deposits usually occur between levee deposits (Qhl) and basin deposits (Qhb). They are prevalent in the Walnut Creek–Concord Valley.

Table 11-3
Mapped Levee and Channel Deposits

Deposit	Map Unit	Descriptions
Flood Basin	Qhfb	Firm to stiff silty clay, clayey silt, and silt, commonly with carbonate nodules and locally with black spherules (manganese or iron oxides). The deposits laterally grade into peaty mud and mud of tidal wetlands (Qhdm). Locally, the deposits are veneered with silty, reddish-brown alluvium of historical age, some of which may have resulted from hydraulic mining in the Sierra Nevada during the late 1800s.

Source: Graymer et al. 2002
Note: Geologic units are listed in order of age (youngest to oldest).

Table 11-4
Mapped Dune Sand Deposits

Deposit	Map Unit	Descriptions
Dune Sands	Qds	Very well sorted fine- to medium-grained eolian sand. Dunes occur mainly in two large northwest–southeast-trending sheets, as well as many small hills, most displaying Barchan morphology. Dunes display as much as 98.4 feet (30 meters) of erosional relief and are presently being buried by basin deposits (Qhb) and delta mud (Qhdm). They probably began accumulating after the last interglacial high stand of sea level began to recede, about 79 ka (Imbrie et al. 1984; Martinson et al. 1987; Hendy and Kennett 2000); continued to form when sea level dropped to its Wisconsin minimum, about 18 ka; and probably ceased to accumulate after sea level reached its present elevation (about 6 ka). Atwater recognized buried paleosols in the dunes, indicating periods of nondeposition (Atwater 1982).

Source: Graymer et al. 2002
ka: thousand years

Lithologically, the two units are nearly identical arkosic fine-grained alluvium from the Sierra Nevada. The upper Modesto Formation is frequently finer-grained silts and sands with a notable eolian component at the surface, capped by a relatively weak soil; whereas the Riverbank Formation is coarser gravel and sand capped by a very strongly developed soil. The Pleistocene Mokelumne River channels that formed these older alluvium deposits bear little relation to the present stream. The modern stream meanders in its floodplain and carries fine-grained sediments, but the Pleistocene rivers cut deep, canyon-like channels into underlying, older fan deposits. These ancient rivers had greater hydraulic competence and carried glacially derived boulders and cobbles much farther downstream than the present stream (Shlemon 1971). The older alluvium units are described in Table 11-5.

Table 11-5
Mapped Older Alluvium

Deposit	Map Unit	Descriptions
Modesto Formation	Qm	Material ranges from loose sand (probably eolian), to fluvial loose sand and silt, to compact silt and very fine sand.
Riverbank Formation	Qr	Riverbank Formation, undivided.

Table 11-5
Mapped Older Alluvium

Deposit	Map Unit	Descriptions
Riverbank Formation	Qry	Younger unit of Riverbank Formation.
Riverbank Formation	Qro	Older unit of Riverbank Formation.

Source: Atwater 1982

11.3.2.1.6 Bedrock Units

The above-described poorly consolidated to unconsolidated Quaternary deposits overlie Cretaceous-to-Tertiary-age sedimentary bedrock, which is generally deeper than 1,000 feet in the Delta (Brocher 2005). For the most part, these sedimentary rocks consist of interbedded marine sandstone, shale, and conglomerate. However, shallow marine, terrestrial, and volcaniclastic sediment deposits are predominated by the late Tertiary. Immediately adjacent to the broader delta-fan-estuary system, rock outcrops of the early Pliocene Montezuma Formation of the Vacaville Assemblage can be found in the Montezuma Hills, north of the western Delta area. This Tertiary-aged sedimentary rock comprises the easternmost outcrops of the northeastern Diablo Range south of the western Delta area (Graymer et al. 2002).

11.3.2.2 Regional and Local Seismicity

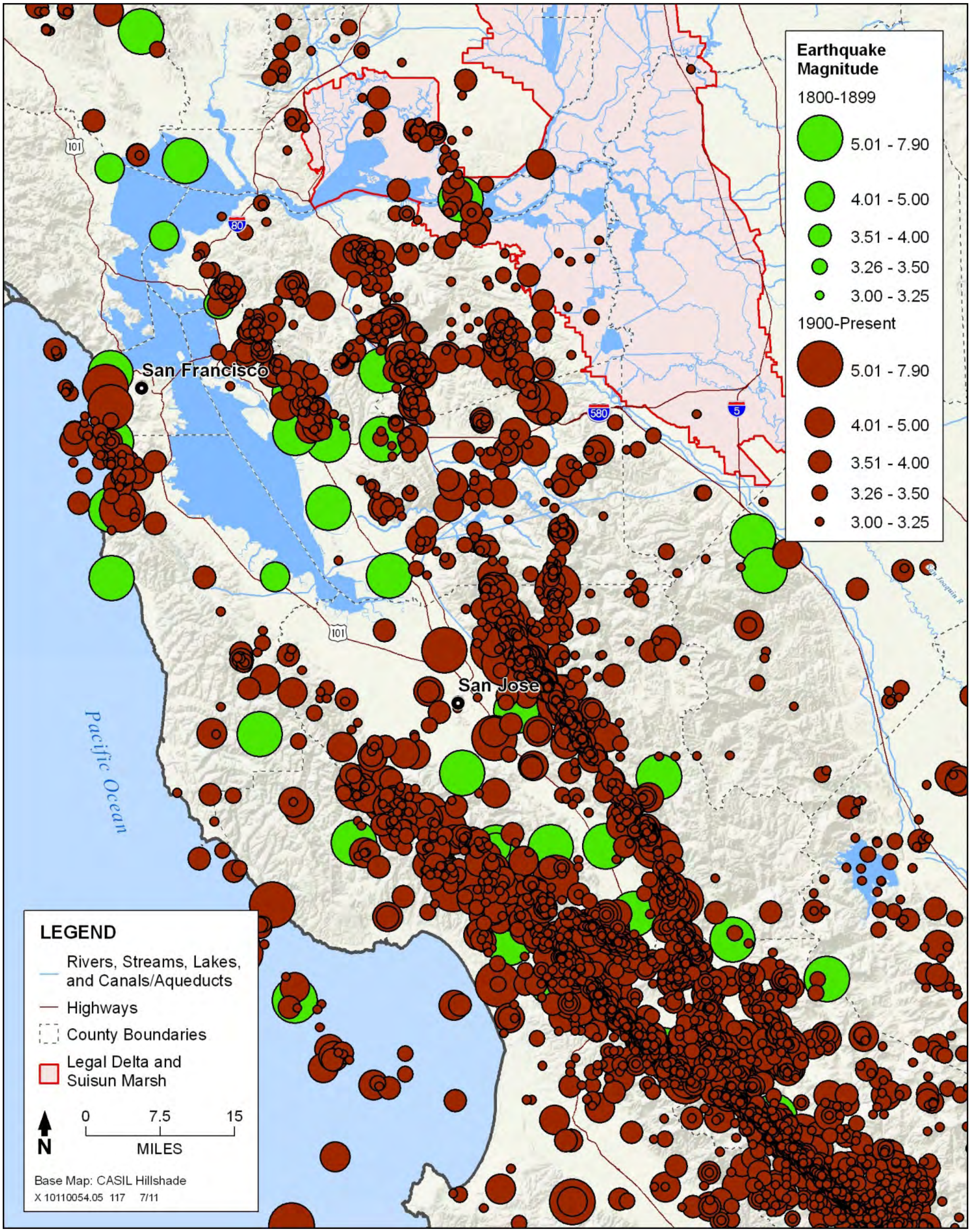
The Delta and Suisun Marsh are located in the eastern portion of the San Francisco Bay region, which is one of the most seismically active areas in the United States. Since 1800, several earthquakes with magnitudes greater than 6.5 have occurred in the region, including the 1868 magnitude 6.8 earthquake on the Hayward fault, the 1906 magnitude 7.9 San Francisco earthquake on the San Andreas fault, and the more recent 1989 magnitude 6.9 Loma Prieta earthquake that occurred in the Santa Cruz Mountains. Figure 11-3 depicts the recorded historical seismicity in the San Francisco Bay region from 1800 to 2006.

In the Delta, the San Andreas fault system dominates the seismicity of the region, and it comprises several major faults, including the San Andreas, Hayward–Rodgers Creek, Calaveras, Concord–Green Valley, Greenville, and Mt. Diablo Thrust faults. In addition to these major faults, many other named and unnamed regional faults accommodate relative motion between the plates and relieve compressional stresses that also act along the plate boundary.

The Working Group on California Earthquake Probabilities (WGCEP) has given a 62 percent probability for one or more large earthquakes (magnitude 6.7 or greater) to occur in the San Francisco Bay region between 2003 and 2032 (WGCEP 2003). This estimate included a 27 percent probability for one or more earthquakes of magnitude 6.7 or greater to occur along the nearby Hayward–Rodgers Creek fault over the same period. Because no major earthquakes have occurred in the San Francisco Bay region over the last several years, this probability will increase with time.

The earthquake source model adopted by WGCEP in the 2003 study includes both the major regional faults and the background seismicity. Because of uncertainties associated with the source data, multiple earthquake source models were considered and weights were assigned to these models on the basis of expert opinion. The results indicated by the study are, therefore, subject to uncertainties.

Figure 11-3
Recorded Historical Seismicity (1800 to 2006) in the San Francisco Bay Region
Source: DWR 2007b



The Delta and Suisun Marsh area has generally experienced low-level seismicity since 1800; no earthquakes with magnitude greater than 5.0 have been observed. Buildings constructed in accordance with the California Building Code are not expected to experience major damage resulting from an earthquake with a magnitude smaller than 5.0. The locations of earthquakes in the Delta since 1966 (Figure 11-4) show no apparent correlation to mapped surface fault traces shown on Figure 11-1 and may be occurring on blind thrust faults. A blind thrust fault is a dipping fault that does not rupture to the ground surface during a seismic event. As discussed in the following sections, the known active seismic sources in the Delta area are believed to be primarily blind thrusts. A few earthquakes with magnitudes between 3.0 and 4.9 were recorded near the Pittsburgh–Kirby Hills fault. Thus, some of these seismic events may have occurred on that fault.

Two relatively recent earthquakes (the 1892 Vacaville-Winters event and the 1983 Coalinga event) have been associated with the Coast Ranges-Sierran Block (CRSB) seismic zone, which is a complex dipping thrust fault zone that goes through the Delta. The epicenter of the 1892 Vacaville-Winters earthquake was approximately 8 miles west of the Delta. The epicenter of the 1983 Coalinga earthquake was approximately 110 miles south of the Delta. Both of these seismic events had a magnitude greater than 6.5.

The San Francisco Bay region has been subject to damaging ground shaking during past earthquakes. Table 11-6 lists the most significant earthquakes that affected the San Francisco Bay region and the damage caused by these earthquakes, as described in the DRMS study (DWR 2007a).

Damage resulting from earthquake ground shaking is typically estimated by MMI, which is a measure of ground shaking that is based on the effects of earthquakes on people and buildings at a particular location. An MMI VII or greater indicates damaging effects on people and buildings.

It is likely that the Delta will experience periodic minor and moderate earthquakes (moment magnitude 6.5 or greater) in the next 50 years. A moderate, or moment magnitude 6.5 or greater earthquake on the major seismic sources in the San Francisco Bay region would affect the Delta with moderate to strong ground shaking and could potentially induce damage in these areas. Strong ground shaking is typically expressed in terms of high peak ground acceleration (PGA) (the maximum acceleration experienced by soil’s particle at ground surface during an earthquake).

11.3.2.2.1 Seismic Sources

Seismic sources or faults can generally be described by one of two activity classes as defined by CGS: active or potentially active. “Active” describes faults that have had displacements within the last 11,400 years. “Potentially active” describes faults showing evidence of displacements during Quaternary time (the past 1.6 million years). A third class of faults, pre-Quaternary-age faults, is classified as “inactive.” This classification is not meant to imply that inactive fault traces will not rupture—but that they have not been shown to have ruptured within the past 1.6 million years—and that the probability of fault rupture is low.

Key characteristics of the seismic sources important to the Delta earthquake hazard potential are summarized in the following sections.

Figure 11-4
Recorded Historical Seismicity (1800 to 2006) in the Suisun Marsh and Delta
Source: DWR 2007b

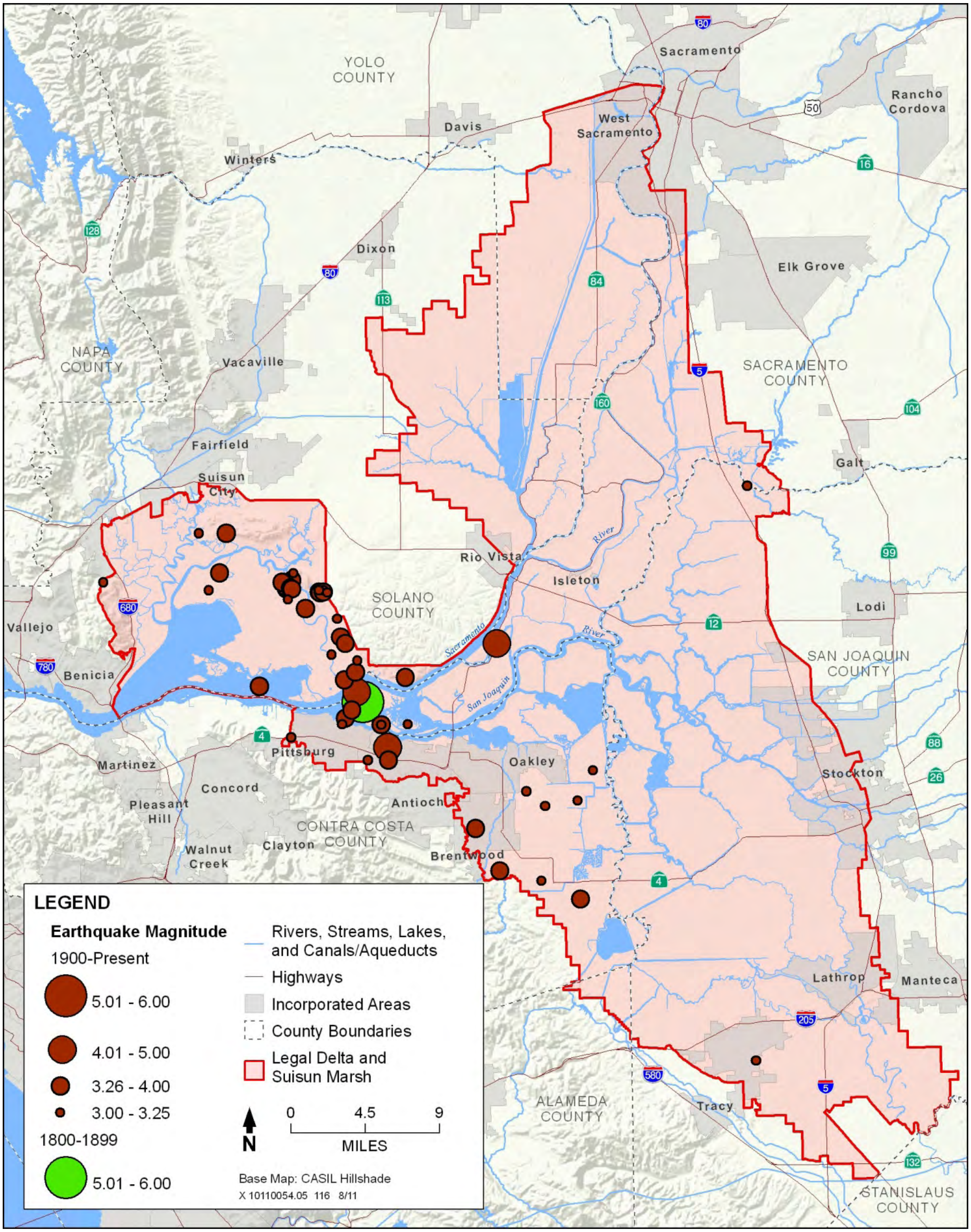


Table 11-6
Significant Earthquakes Affecting the San Francisco Bay Region

Date	Intensity	Fault	Location	Damage Incurred
October 21, 1868	M_L = 6.8	Southern Hayward	San Francisco Bay Area, San Jose	Heavy damage sustained in towns along the Hayward fault in the eastern San Francisco Bay Area.
April 19 and 21, 1892	**M** = 6.2 to 6.5	CRSB Seismic Zone	Winters/ Vacaville	Damage to the communities of Vacaville, Dixon, and Winters and to the surrounding rural areas. Brick buildings were damaged, and one man was killed by falling bricks.
March 31, 1898	MMI = VIII or greater M_L = 6.7	—	Mare Island in San Pablo Bay	Buildings damaged in areas around the San Francisco Bay Area.
April 18, 1906	**M** = 7.9	San Andreas	San Francisco	Widespread damage in Northern California. Ground shaking and fire caused the deaths of more than 3,000 people and injured approximately 225,000 people.
May 2, 1983	**M** = 6.4	CRSB Seismic Zone	Coalinga	$10 million in property damage and injured 94 people.
April 24, 1984	**M** = 6.2	Calaveras	Morgan Hill	$7.5 million in damage. In San Jose, cracks formed in some walls; plaster fell; many items were thrown from store shelves; and some chimneys cracked.
October 17, 1989	**M** = 6.9	San Andreas	Santa Cruz Mountains	$6 billion damage, 62 deaths, 3,500 injured, and 12,000 people were displaced from homes.
October 30, 2007	**M** = 5.6	Calaveras	Northeast of San Jose	Strong shaking, no damage reported.

Source: DWR 2007a
M_L: Richter Magnitude
M: Moment Magnitude
MMI: Modified Mercalli Intensity

Faults with Surface Expression

The approximate locations of the active and potentially active seismic sources in the San Francisco Bay region and in the Delta are plotted on Figures 11-3 and 11-4, respectively. The faults with surface expression known to cross the Delta are the Pittsburgh–Kirby Hills and the Concord–Green Valley faults. The Pittsburgh–Kirby Hills fault is mapped crossing the Suisun Marsh from near the city of Fairfield at the north to the city of Pittsburg at the south. The Concord–Green Valley fault crosses the western part of the Suisun Marsh. Note that the Cordelia fault terminates close to the northern boundary of the Suisun Marsh.

Other major faults having surface expression in the San Francisco Bay region that have the potential for generating significant earthquake ground shaking in the Delta include the San Andreas, Hayward-Rodgers Creek, Calaveras, Concord–Green Valley, and Greenville faults. The San Andreas, Hayward–Rodgers Creek, and Calaveras faults are regional seismic sources that, although at large distances from the Delta and Suisun Marsh, can induce significant ground shaking because of their potential for generating large-magnitude earthquakes.

The maximum earthquake moment magnitudes, closest distances to the Delta, long-term geologic slip rates, and faulting mechanism assigned to these major active faults are presented in Table 11-7. Earthquake moment magnitude is a measure of earthquake size based on the energy released. This definition was developed in the 1970s, to replace the Richter magnitude scale; and it is considered a better representation of earthquake size. The geologic slip rate is the rate that the opposite sides of a fault move with respect to one another. Faulting style describes the direction of movements along the fault. A strike-slip fault indicates lateral sliding of the sides of a fault past each other.

Table 11-7
Characteristics of Major Seismic Sources in the San Francisco Bay Region

Fault (closest to farthest)	Distance from Delta and Suisun Marsh[a] (miles)	Slip Rate[b] (inch/year)	Maximum Earthquake[b] (moment magnitude)	Faulting Style
Concord–Green Valley	0.0	0.20 ± 0.12	6.7	Strike-slip
Pittsburgh–Kirby Hills	0.0	0.02 ± 0.08	6.7	Strike-slip
Greenville	6.2	0.16 ± 0.08	6.9	Strike-slip
Hayward–Rodgers Creek	12.4	0.35 ± 0.08	7.3	Strike-slip
Calaveras	16.8	0.16 to 0.79	6.9	Strike-slip
San Andreas	30.0	0.94 ± 0.12	7.9	Strike-slip

Source: DWR 2007a
[a] Closest distance from fault trace to Delta
[b] Largest values assigned (DWR 2007a)

Blind Thrust Faults

The seismic sources underlying the Delta are primarily “blind” thrusts (Table 11-8). A blind thrust is a seismic source that is not expected to rupture to the ground surface during an earthquake event but is still capable of producing large and damaging ground shaking. As shown in Table 11-8, the probability of activity is a measure of certainty, based on the available data, that a seismic source is active. A probability of 1.0 indicates that the data strongly suggest an active fault. A reverse-oblique faulting style describes fault movements where one side of a fault moves upward relative to the other side (an up-dip sense of movement) with additional components of lateral movement. Such faults originate as a result of compression in the earth’s crust.

Table 11-8
Characteristics of Blind Thrust Faults in the Delta

Fault (closest to farthest)	Probability of Activity	Slip Rate (inch/year)	Maximum Earthquake (moment magnitude)	Faulting Style
Thornton Arch	0.2	0.002 to 0.006	6.0 to 6.5	Reverse-oblique
Montezuma Hills	0.5	0.002 to 0.02	6.0 to 6.5	Reverse-oblique
Vernalis	0.8	0.003 to 0.02	6.25 to 6.75	Reverse-oblique
Southern Midland	0.8	0.004 to 0.04	6.6	Reverse-oblique
West Tracy	0.9	0.003 to 0.02	6.25 to 6.75	Reverse-oblique

Table 11-8
Characteristics of Blind Thrust Faults in the Delta

Fault (closest to farthest)	Probability of Activity	Slip Rate (inch/year)	Maximum Earthquake (moment magnitude)	Faulting Style
Black Butte and Midway	1.0	0.004 to 0.04	6.25 to 6.75	Reverse-oblique
Northern Midland	1.0	0.004 to 0.04	6.0 to 6.5	Reverse-oblique

Source: DWR 2007a

The Midland fault is an approximately north-striking blind thrust fault that dips to the west and underlies the central region of the Delta area. The fault is at least 37 miles long, and gas explorations conducted in the area indicate that it is not exposed at the ground surface (California Division of Oil and Gas 1982). The Midland fault is divided into a Northern Midland Zone, which characterizes the northwest-striking fault splays north of the city of Rio Vista, and a Southern Midland fault, which extends southward to a point near the Clifton Court Forebay.

The Montezuma Hills seismic source is modeled as a source zone located between the Delta and Suisun Marsh near the city of Rio Vista. The zone extends southward to the Sherman Island area.

The Thornton Arch seismic zone is defined to represent the possible existence of active buried structures near the Thornton and West Thornton–Walnut Grove gas field near the Delta Cross Channel area. After considering the best available evidence to date, the DRMS study adopted a low probability of activity and a low slip rate for this zone (DWR 2007a).

The West Tracy, Vernalis, Black Butte, and Midway faults are parts of the CRSB seismic zone. The CRSB is a complex zone of thrust faulting that defines the boundary between the Coast Ranges block to the west and the Sierran basement rocks of the Sacramento–San Joaquin valleys to the east. The West Tracy fault is mapped near the Clifton Court Forebay and has a total length of about 21 miles. The fault strikes in a northwest–southeast direction and dips moderately to steeply to the west. The Vernalis fault is mapped at the southern end of the Delta area, extending between the city of Tracy and the city of Patterson, at a minimum length of about 19.2 miles. Similar to the West Tracy fault, the Vernalis fault is a moderately to steeply west-dipping fault (DWR 2007a). The Black Butte fault is also a northwest–southeast striking fault, located approximately 6 miles southeast of Tracy. It also dips moderately to steeply to the west. The Midway fault similarly strikes northwest–southeast and is separated from the northwest end of the Black Butte fault by an echelon step across a small west–northwest-trending anticline. DWR (2008) characterized the Black Butte and Midway faults as a single structure (Figure 11-1).

Seismic Zones

To account for seismicity not associated with known faults, such as random or floating earthquakes, the Coast Ranges and Central Valley seismic zones were developed for the DRMS study (DWR 2007a). The maximum earthquake magnitudes assigned to these seismic zones are moment magnitude 6.5 ± 0.3.

The Cascadia Subduction Zone extends from Cape Mendocino, California, to Vancouver Island, British Columbia. Although this seismic zone is located at a large distance from the project area, it cannot be ignored because of its potential for generating very large-magnitude earthquakes (earthquakes with moment magnitudes of about 9.0) that even at such distances could cause significant ground shaking in the Delta. A large-magnitude earthquake tends to produce strong long-period motions even at large distances from the energy source. Long-period ground motions are important in assessments of risk to linear structures such as pipelines and levees.

Because of the distances from the Delta, only very large (megathrust) events along the interface of the Cascadia Subduction Zone were considered in the DRMS study (DWR 2007a). The Wong and Dober (2007) megathrust model was adopted, with a maximum moment magnitude of 9 ± 0.5 and a recurrence interval of 450 ± 150 years.

An alternative model was considered by USGS for the Cascadia interface. The 2007 USGS model (Petersen et al. 2008) considers two weighted probability fault-rupture scenarios: (1) megathrust events (magnitude 9.0 ± 0.2) that rupture the entire interface zone every 500 years (weight of 0.67) and (2) smaller events (magnitude 8.0 to 8.7) that float over the interface zone and rupture the entire zone over a period of about 500 years (weight of 0.33).

11.3.2.3 Geologic and Seismic Hazards

The geologic and seismic hazards discussed in this section include surface fault rupture, earthquake ground shaking, seismically induced liquefaction and related soil instability, and slope instability. Soil instability resulting from liquefaction includes compaction or settlement, temporary loss of bearing capacity, lateral spreading, increased lateral earth pressures, and temporary buoyancy effects on buried structures.

11.3.2.3.1 Surface Fault Ruptures

Fault Rupture Zones

The Alquist-Priolo (AP) Earthquake Fault Zoning Act, passed in 1972, required the establishment of earthquake fault zones (known as “special studies zones” prior to January 1, 1994) along known active faults in California. The State guidelines for assessing fault rupture hazards are explained in CGS Special Publication 42 (Bryant and Hart 2007). Strict regulations for development in these fault zones are enforced to reduce the potential for damage resulting from fault displacement.

According to the available maps, the Suisun Marsh is crossed by the AP fault zone designated by CGS for the Concord fault. This fault zone is mapped crossing the Suisun Marsh from southeast to northwest, north of the city of Concord. The AP fault zone designated for the Greenville fault is mapped outside and to the south of the Delta.

As discussed previously, the Delta is underlain by blind thrusts that are considered active or potentially active, but they are not expected to rupture to the ground surface. Blind thrust fault ruptures generally terminate before they reach the surface. They may produce ground manifestations (such as ground surface bulging) during rupture at depth. The Pittsburgh–Kirby Hills fault is mapped crossing Suisun Marsh; however, CGS has not developed an official AP fault zone for this fault.

Fault Offsets

An estimate of fault offset (fault movement or displacement during a fault-rupture related seismic event) is important for assessing possible future impacts. The amount of fault offset depends mainly on earthquake magnitude and location along the fault trace. Fault offset can occur on a single fault plane or over a narrow zone where displacements are distributed over the zone. Fault rupture can also be caused by rupture on a neighboring fault (secondary fault rupture).

Empirical relationships are typically used to estimate fault offsets. The relationships provide estimates of fault displacements, such as average and maximum offsets, as a function of fault parameters. The average and maximum fault offsets for the Concord and the Pittsburgh–Kirby Hills faults (Table 11-9) were estimated using the relationships of Wells and Coppersmith (1994).

Table 11-9
Estimated Fault Rupture Offsets for Concord and Pittsburgh–Kirby Hills Faults

Fault	Maximum Earthquake (moment magnitude)	Average Offset[a] (inch)	Maximum Offset[a] (inch)	Faulting Style
Concord[b]	6.7	10.6–38.6	13.4–63	Strike-slip
Pittsburgh–Kirby Hills	6.7	10.6–38.6	13.4–63	Strike-slip

Source: Estimated using the relationships of Wells and Coppersmith (1994).
[a] The range represents values ±1 standard deviation.
[b] The maximum magnitude of the Concord–Green Valley fault system was used.

Although the Midland fault is characterized as a blind thrust, there seems to be anomalous vertical relief at the base of the peat (or at the top of the sand layer) across the fault traces. The available data indicate a modest 6.6 to 9.8-foot west-side-up step at the base of the peat across the surface trace of the Midland fault (DWR 2007a). Thus the nature of displacement on the Midland fault may be more complex than simple thrusting along an inclined fault surface.

11.3.2.3.2 Earthquake Ground Shaking

The potential for earthquake ground shaking in the Delta was evaluated using the Probabilistic Seismic Hazard Analysis (PSHA) method (DWR 2007a). This method permits the explicit treatment of uncertainties in source geometry and parameters, as well as ground motion estimation. In a PSHA, the probabilities of exceeding various levels of ground motion at a site are calculated by considering (1) seismic source locations and geometry and rates of various earthquake magnitudes, and (2) ground motion attenuation from the energy source to the site. The uncertainties associated with source parameters and ground motion estimation are incorporated in the analysis.

The DRMS study (DWR 2007a) used the Next Generation Attenuation (NGA) relationships developed for western United States earthquakes for the crustal faults, blind thrusts, and seismic zones discussed previously. At the time of the study, only three of the NGA relationship models were available, and these were used with equal weights (Chiou and Youngs 2006[1]; Campbell and Bozorgnia 2007[2]; Boore and Atkinson 2007[3]). For the Cascadia Subduction Zone, DWR used the relationships of Youngs et al. (1997)[4]; Atkinson and Boore (2003)[5]; and Gregor et al. (2007)[6], and all three were used with equal weights.

The PSHA was conducted at six selected locations in the Delta area (Clifton Court, Delta Cross Channel, Montezuma Slough, Sacramento, Sherman Island, and Stockton) for 4 years: 2005, 2050, 2100, and 2200.

[1] As cited in DWR 2007a: Chiou, B. S-J., and R. R. Youngs. 2006. Chiou and Youngs PEER NGA Empirical Ground Motion Model for the Average Horizontal Component of Peak Acceleration and Pseudo-Spectral Acceleration for Spectral Periods of 0.01 to 10 Seconds. Interim Report for USGS Review. Revised July 10, 2006.

[2] As cited in DWR 2007a: Campbell, K. W., and Y. Bozorgnia. 2007. Campbell-Bozorgnia NGA Ground Motion Relations for the Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters. Pacific Earthquake Engineering Research Center Report, PEER 2007/02.

[3] As cited in DWR 2007a: Boore, D. M., and G. M. Atkinson. 2007. Boore-Atkinson NGA Ground Motion Relations for the Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters. Pacific Earthquake Engineering Research Center Report, PEER 2007/01.

[4] As cited in DWR 2007a: Youngs, R. R., S-J. Chiou, W. A. Silva, and J. R. Humphrey. 1997. Strong Ground Motion Attenuation Relationships for Subduction Zone Earthquakes. Seismological Society of America. Seismological Research Letters. Volume 68 (January/February): 58–73.

[5] As cited in DWR 2007a: Atkinson, G. M., and D. M. Boore. 2003. Empirical Ground-motion Relations for Subduction-zone Earthquakes and Their Application to Cascadia and Other Regions. Bulletin of the Seismological Society of America. Volume 93(4): 1703–1729. August 2003.

[6] As cited in DWR 2007a: Gregor et al. 2007. Written communication to URS Corporation/Jack R. Benjamin & Associates, Inc.

The results are expressed in terms of hazard curves that relate the intensity of ground motion (PGA and response spectral accelerations) to annual exceedance probability (probability that a specific value of ground motion intensity will be exceeded in a given year). The distributions of hazard curve (the 5th, 15th, mean, median [50th], 85th, and 95th percentile hazard curves) were calculated at the six selected locations for PGA and 1.0-second spectral acceleration. The seismic hazard analysis was performed assuming a stiff soil site condition with an average shear-wave velocity of 1,000 feet per second in the top 100 feet or 30 meters (DWR 2007a).

Controlling Seismic Sources

The seismic sources expected to dominate the ground motions at a specific location (known as controlling seismic sources) vary depending on the location, ground motion probability level (or return period), and ground motion frequency (or period). Table 11-10 summarizes the controlling seismic sources at the six selected sites in 2005 for PGA and 1.0-second spectral acceleration at ground motion return periods of 100 and 2,475 years.

Table 11-10
Controlling Seismic Sources in 2005

Location	Controlling Source for PGA	Controlling Source for 1.0-second Spectral Acceleration
100-year Return Period		
Clifton Court	Southern Midland Mt. Diablo	Mt. Diablo Hayward–Rodgers Creek
Delta Cross Channel	Southern Midland Northern Midland Zone	Mt. Diablo
Montezuma Slough	Concord–Green Valley	Concord–Green Valley
Sacramento	Northern Midland Zone	Mt. Diablo San Andreas
Sherman Island	Southern Midland	Southern Midland Hayward–Rodgers Creek San Andreas
Stockton	Southern Midland Hayward–Rodgers Creek Calaveras	Hayward–Rodgers Creek San Andreas
2,475-year Return Period		
Clifton Court	Southern Midland	Southern Midland
Delta Cross Channel	Southern Midland Northern Midland Zone	Cascadia Subduction Zone Southern Midland
Montezuma Slough	Pittsburg-Kirby Hills	Pittsburg-Kirby Hills
Sacramento	Northern Midland Zone	Cascadia Subduction Zone
Sherman Island	Southern Midland Montezuma Hills Zone	Southern Midland
Stockton	Southern Midland	Cascadia Subduction Zone

Source: DWR 2007a

Site Soil Amplifications

Thick deposits of peaty and soft soils tend to amplify earthquake ground motions, especially for the long-period motions such as the 1.0-second spectral acceleration. The earthquake ground motions developed for the Delta as part of the DRMS study are applicable for a stiff soil site condition. Therefore, these motions are expected to change as they propagate upward through the peaty and soft soils from the stiffer alluvium underlying the Delta. According to studies by others, the acceleration amplification factor from the stiff base layer to the levee crown is on the order of 1 to 2 (CALFED 2000).

72-year Return Period Peak Ground Motion

A return period is the frequency at which a given fault rupture event or a ground shaking event recurs. The calculated mean PGA and 1.0-second spectral acceleration values for a 72-year ground motion return period (or an annual frequency of 0.01388) in 2005 and 2200 are presented in Table 11-11. The calculated ground motions in 2050 and 2100 are between these values. The 72-year return period corresponds to approximately a 50 percent probability of exceedance in 50 years. The ground motions were calculated for a stiff soil condition with an average shear-wave velocity of 1,000 feet per second in the top 100 feet.

144-year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 144-year ground motion return period (or an annual frequency of 0.00694) in 2005 and 2200 are presented in Table 11-11. The calculated ground motions in 2050 and 2100 are between these values. The 144-year return period corresponds to approximately 30 percent probability of exceedance in 50 years.

Table 11-11
Calculated Mean Peak Ground Motions at Selected Sites for Various Return Periods
(for Stiff Soil Site, Vs100ft = 1,000 feet per second)

	Return Period									
	72 years		144 years		475 years		975 years		2,475 years	
Location	**2005**	**2200**	**2005**	**2200**	**2005**	**2200**	**2005**	**2200**	**2005**	**2200**
Mean Peak Ground Acceleration in g										
Clifton Court	0.18	0.21	0.24	0.27	0.39	0.41	0.49	0.51	0.66	0.67
Delta Cross Channel	0.13	0.14	0.16	0.18	0.24	0.25	0.29	0.29	0.36	0.36
Montezuma Slough	0.23	0.27	0.31	0.34	0.46	0.49	0.57	0.60	0.74	0.75
Sacramento	0.11	0.12	0.14	0.14	0.20	0.20	0.24	0.24	0.29	0.29
Sherman Island	0.20	0.23	0.27	0.29	0.41	0.43	0.49	0.52	0.64	0.66
Stockton	0.12	0.13	0.15	0.17	0.22	0.23	0.25	0.27	0.31	0.33
Mean 1.0-second Spectral Acceleration in g (5 percent damping)										
Clifton Court	0.20	0.24	0.28	0.32	0.46	0.50	0.60	0.63	0.83	0.85
Delta Cross Channel	0.15	0.17	0.20	0.23	0.30	0.33	0.37	0.40	0.48	0.50
Montezuma Slough	0.24	0.29	0.33	0.38	0.53	0.57	0.66	0.71	0.89	0.93
Sacramento	0.13	0.15	0.17	0.19	0.26	0.28	0.32	0.34	0.42	0.44
Sherman Island	0.22	0.26	0.29	0.34	0.46	0.50	0.59	0.62	0.78	0.80
Stockton	0.14	0.17	0.19	0.22	0.28	0.31	0.34	0.38	0.44	0.47

Source: DWR 2007a
Notes:
g = acceleration due to gravity, 32.2 feet per second^2
Vs = shear-wave velocity

475-year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 475-year ground motion return period (or an annual frequency of 0.0021) in 2005 and 2200 are presented in Table 11-11. The calculated ground motions in 2050 and 2100 are between these values. The 475-year return period corresponds to approximately 10 percent probability of exceedance in 50 years.

975-year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 975-year ground motion return period (or an annual frequency of 0.00102) in 2005 and 2200 are presented in Table 11-11. The calculated ground motions in 2050 and 2100 are between these values. The 975-year return period corresponds to approximately 5 percent probability of exceedance in 50 years.

2,475-year Return Period Ground Motion

The calculated mean PGA and 1.0-second spectral acceleration values for a 2,475-year ground motion return period (or an annual frequency of 0.0004) in 2005 and 2200 are presented in Table 11-11. The calculated ground motions in 2050 and 2100 are between these values. The 2,475-year return period corresponds to approximately 2 percent probability of exceedance in 50 years.

The data in Table 11-11 indicate that ground motion decreases from west to east as the distance to the San Andreas fault system increases. Also, the calculated ground motions are not sensitive (i.e., only increase slightly) to the assumed time interval from the last major earthquake (from 2005 to 2200).

The 2008 USGS National Seismic Hazard Maps provide the values of PGA and 1.0-second spectral acceleration for the 475- and 2,475-year return periods. Table 11-12 compares the ranges of PGA and 1.0-second spectral acceleration calculated in the DRMS study (DWR 2007a) to those estimated from the USGS maps (USGS 2009).

Note that the 2008 USGS maps were developed for a reference site condition with an average shear-wave velocity of 2,500 feet per second (about 760 meters per second) in the top 100 feet (Petersen et al. 2008). Consequently, the mapped values cannot be directly compared to those calculated in the DRMS study, which assumed a site condition with an average shear-wave velocity of 1,000 feet per second (DWR 2007a).

Table 11-12
Comparison of Ground Motions Calculated in the DRMS Study to Estimated 2008 USGS Mapped Values

	Range of Mean Peak Ground Acceleration in g		Range of Mean 1.0-second Spectral Acceleration in g (5 percent damping)	
Ground Motion Return Period	**DRMS Study[a]**	**USGS 2008 Maps[b]**	**DRMS Study[a]**	**USGS 2008 Maps[b]**
475 years	0.20–0.46	0.20–0.40	0.26–0.53	0.14–0.30
2,475 years	0.29–0.74	0.30–0.70	0.42–0.89	0.25–0.50

Sources: DWR 2007a; USGS 2009
[a] Ranges of calculated ground motion at the six selected sites in the Delta (V_{s100ft} = 1,000 feet per second)
[b] Approximate ranges of ground motion over the Delta (V_{s100ft} = 2,500 feet per second)

11.3.2.3.3 Liquefaction

Liquefaction is a process whereby strong ground shaking causes loose and saturated soil sediments to lose strength and behave as a viscous fluid. This process can cause ground deformations and failures, increases in lateral earth pressure, and temporary loss of soil-bearing capacity, resulting in damage to structures and levees. Ground failures can take the forms of lateral spreading, differential and/or total compaction or settlement, and slope failure. Liquefaction can also increase the potential for temporarily increased buoyancy of buried structures (potentially causing them to float upwards).

The potential for liquefaction may result in requirements for specialized approaches to foundation construction for structures, specialized approaches to pipeline construction, and specialized designs for pavement. The cost of construction where such hazards are present can therefore be much higher than for non-impacted areas. Where such hazards are severe, avoidance may be the only economically viable mitigation strategy.

The Delta is underlain at shallow depths by various channel deposits and recent silty and sandy alluvium. Some of the existing levee materials also consist of uncompacted, silty and sandy soils. These loose, saturated, silty and sandy materials are susceptible to liquefaction during future earthquakes. Soil liquefaction is also a function of ground motion intensity and shaking duration. Longer ground shaking, even at a lower intensity, may cause liquefaction as the soil is subject to more repeated cycles of loading. Longer duration shaking is typically associated with larger magnitude earthquakes, such as earthquakes that occur on the San Andreas, Hayward, and Calaveras faults.

Historical Occurrences of Liquefaction

Ground manifestation associated with liquefaction during the 1906 San Francisco earthquake was reported in three project area locations. Youd and Hoose (1978) reported settlements up to 11 feet south of Fairfield along the Southern Pacific Railway through the Suisun Marsh. Ground settlement of several inches was reported at the Southern Pacific Bridge Crossing over the San Joaquin River in Stockton, and settlement of 3 feet was reported at a bridge crossing over Middle River approximately 10 miles west of Stockton (Youd and Hoose 1978). No ground manifestations were reported in the Delta during the more recent 1989 Loma Prieta earthquake (Knudsen et al. 2000).

The lack of ground manifestation during past earthquakes does not indicate that the Delta is not susceptible to liquefaction or that areas within the Delta have not liquefied in past earthquakes. Levees constructed of, or founded on, similar materials have liquefied and failed in many parts of the world (e.g., Central California, Mexico, and Japan) in recent earthquakes. Since the levees were constructed beginning in the 1870s, the Delta and the Suisun Marsh have not experienced the levels of ground shaking shown in Table 11-12. The shallower soil deposits in the Delta tend to be loose and saturated, and given that moderate-to-high ground motions can be expected during future earthquakes, the potential for liquefaction to occur in the Delta is judged to be moderate to high.

Areas Susceptible to Liquefaction

Along the Delta levees, loose silty and sandy soils are present in the levee embankments and in the underlying foundation soils. When saturated, such loose soils are susceptible to liquefaction during earthquake events. Because the levees are constructed (not naturally occurring), the uncompacted loose silty and sandy soils are likely to be more continuous than those present in the foundation soils (CALFED 2000). Areas with larger lateral continuity of liquefied soil are expected to experience more ground failure. The available data also indicate that the levees protecting Sherman Island have extensive layers of liquefiable sandy soils, more so than other levees in the Delta (CALFED 2000), as previously discussed in Section 5, Delta Flood Risk.

Maps of areas susceptible to liquefaction within the San Francisco Bay region indicate that the Suisun Marsh and areas in the Delta near Cache Slough and Contra Costa County shorelines are underlain by soil deposits having liquefaction susceptibility that generally ranges from low to high, with a few areas of very high susceptibility (Knudsen et al. 2000). This analysis did not include other areas of the Delta. The soils in the Suisun Marsh generally have moderate liquefaction susceptibility (Witter et al. 2006). These maps do not extend to the entire Delta area; no information on liquefaction susceptibility for the entire Delta area is available at this time.

Liquefaction Hazard Maps Prepared by California Geological Survey

No official Seismic Hazard Zones maps for liquefaction potential have been developed by CGS for the Delta. The closest available maps are those for the Las Trampas Ridge quadrangle, southwest of the Delta, and the Livermore and Altamont quadrangles, south of the Delta.

11.3.2.3.4 Areas Susceptible to Slope Instability

No natural areas susceptible to slope instability (landslides, debris flows, surficial slumping, and soil creep) have been identified within the Delta. Constructed fill slopes along levees are variably susceptible to such events based on their steepness, soil makeup, level of saturation, and state of density.

The stability of a fill slope can be reduced through erosion and undercutting or removal of supporting materials at the toe of the slope due to mechanisms such as scouring and by increased pore water pressure within the slope, by disturbances such as excavation and bioturbation, and by weathering or decomposition of supporting soils. Strong earthquake ground shaking often contributes to slope failures.

Historical Occurrences of Landslides and Levee Failure

Since 1900, at least 166 levee failures or breaches have been reported that resulted in flooding the Delta islands and tracts. Section 3, Water Resources, shows the historical and approximate locations of island flooding in the Delta. None of these levee breaches is believed to be directly caused by earthquake ground shaking. The probable causes of the levee breaches have been water overtopping levees during high tides; erosion, piping, and seepage though the levee embankment and foundation soils; and burrowing animals.

Because the topography of the Delta is relatively flat, the potential for landslides at locations outside the levees is considered low. No maps or records on the historical occurrences of slope failure are readily available for areas outside the levees.

Areas Susceptible to Landslides

The known areas susceptible to slope failure within the Delta are located along the levee system, as described above.

Landslide Hazard Maps Prepared by California Geological Survey

No official Seismic Hazard Zones maps for earthquake-induced landslide potential have been developed by CGS for the Delta. The closest available maps are those for the Las Trampas Ridge quadrangle, located to the southwest of the Delta, and the Livermore and Altamont quadrangles, located to the south of the Delta.

Note that the Seismic Hazard Zones map for the Altamont quadrangle indicates areas south of the Delta where previous occurrences of landslide movement or potential for permanent ground displacement exist.

11.3.2.3.5 Ground Failure and Seismically Induced Soil Instability

Compaction and Settlement

Earthquake ground motions can cause compaction and settlement of soil deposits because of rearrangement of soil particles during shaking. The amount of settlement depends on ground motion intensity and duration and degree of soil compaction; looser soils subjected to higher ground shaking will settle more. Empirical relationships are commonly used to provide estimates of seismic-induced settlement. In these relationships, ground shaking can be represented by PGA and magnitude, and soil compaction is typically measured by Standard Penetration Test blow-counts (N-values). Excessive total and differential settlements can cause damage to buried structures, including utilities that in turn may initiate larger failure to levees and other aboveground facilities.

The potential for seismically induced soil compaction and settlement must be determined using site-specific data.

Loss of Bearing Capacity

Liquefaction can also result in temporary loss of bearing capacity in foundation soils, which has the potential to cause foundation and pipeline failures during and immediately after an earthquake event.

The potential for liquefaction-induced soil-bearing capacity loss must be determined using site-specific data.

Lateral Spreading

Soil lateral spreading or horizontal movement can be initiated during an earthquake event. Lateral spreading could occur even on gently sloping ground or flat ground with a nearby free face when the underlying soils liquefy. The amount of horizontal movement depends on ground motion intensity, the slope of the ground, soil properties, and conditions of lateral constraint (free-face or non-free-face condition).

The potential for lateral spreading must be determined using site-specific soil data and topographic information.

Increased Lateral Pressures

Liquefaction can increase lateral earth pressures on walls and buried structures. As soils liquefy, earth lateral pressure will approach that of a fluid-like material.

The potential for increased earth lateral pressure due to liquefaction must be determined using site-specific data at the locations of walls and buried structures.

Buoyancy

Liquefaction can cause buried pipes and structures to become buoyant. The potential for buoyancy due to liquefaction must be determined using site-specific data at the locations of buried pipes and structures.

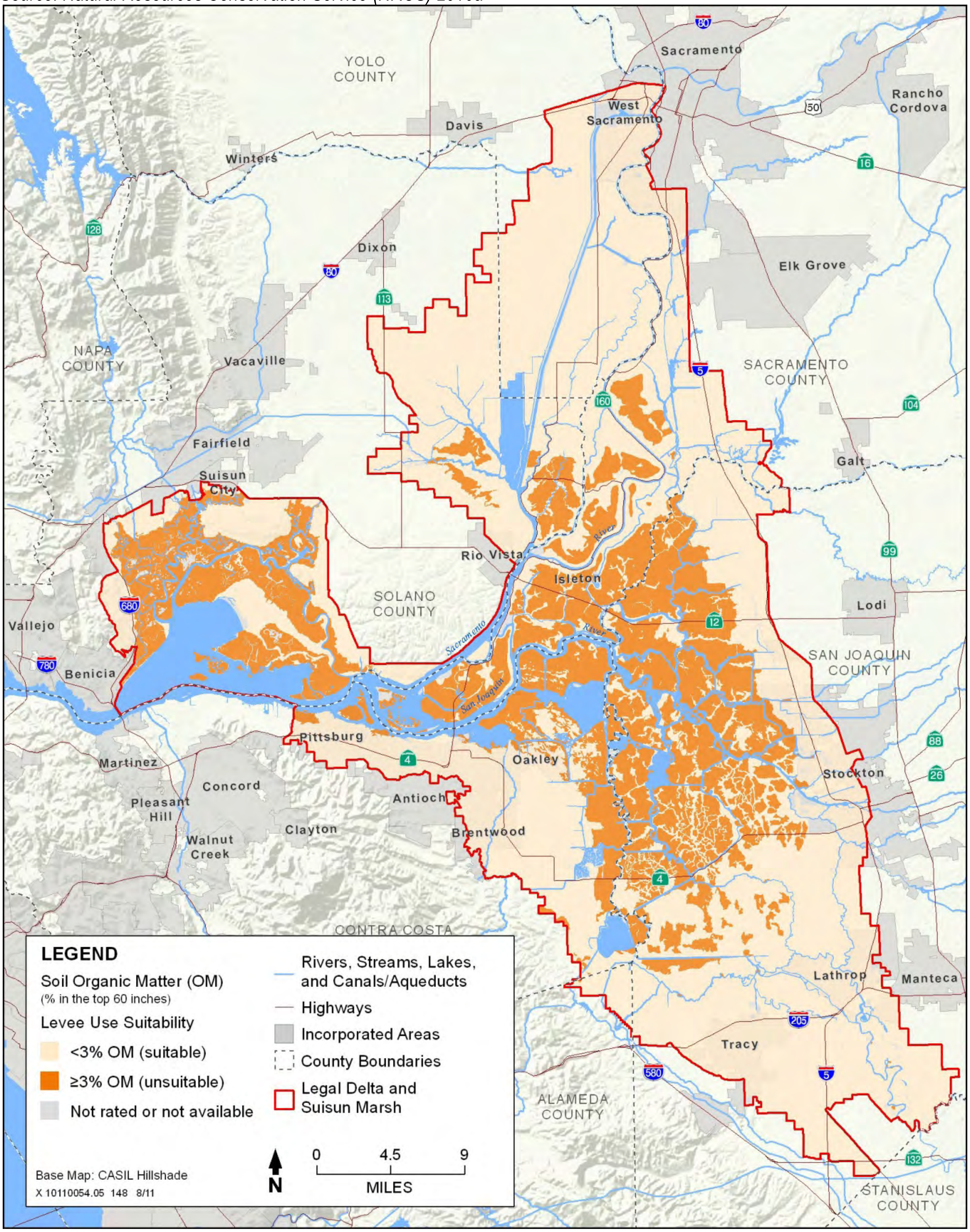
11.3.2.3.6 Soil Suitability for Levees

Many soil properties determine suitability for levees. Soil texture, presence of organics or coarse fragments, and content of sodium and salts will all affect the potential for success when used to create levees. The majority of the project area is rated as having limitations for levees (Figure 11-5). Limitations within the project area include the presence of expansive soils (as discussed above), presence of organic materials, and presence of soil textures with high piping potential (poorly graded materials with low plasticity).

11.3.3 Other Areas of California

As described in Section 2A, Proposed Project and Alternatives, facilities could be constructed, modified, or reoperated in the Delta watershed and areas outside of the Delta that use Delta water, in addition to the Delta. Water use could also be modified in the areas outside of the Delta that use Delta water, in addition to the Delta. Those areas include a wide range of geological conditions that range from conditions described for the Delta to areas with more seismic activity. Geological conditions are considered by agencies when approving projects to reduce risks associated with the local geological characteristics.

Figure 11-5
Soil Suitability for Levees Based on Organic Content of Soils
Source: Natural Resources Conservation Service (NRCS) 2010a



11.4 Environmental Setting (Soils)

This section describes the soil resources within the study area, and soil characteristics that could contribute to potential impacts as a result of adopting the Delta Plan or implementing the alternatives. The discussion focuses primarily on soils of the Delta and Suisun Marsh, since the Delta Plan policies and recommendations would likely have the greatest impact within the Delta. However, it is recognized that actions affecting soils could be undertaken in areas outside the Delta and a general discussion of soils in other areas is provided.

11.4.1 Major Sources of Information

The soils information provided in this section is based largely on NRCS soil surveys for the counties within the project area and the online Soil Survey Geographic database. Other sources include DWR and CALFED publications, academic technical reports and publications, and county and city general plans.

11.4.2 Delta and Suisun Marsh

Soil formation and development is driven by a number of factors, including climate, topography, biological activity, parent material, and time. Soils in the Delta were formed as the result of geologic processes over approximately the past 7,000 years. These processes produced landward accumulation of sediment behind the bedrock barrier at the Carquinez Strait, forming marshlands comprising approximately 100 islands that were surrounded by hundreds of miles of channels (Weir 1950). Generally, mineral soils formed near the channels during flood conditions and organic soils formed on marsh island interiors as plant residues accumulated faster than they could decompose. Prior to the mid-1800s, the Delta was a vast marsh and floodplain, under which peat soils developed to a thickness of up to 30 feet in some areas (Weir 1950).

Management of Delta soils for agriculture and flood control over the past 100 years caused dramatic changes to soils and the overall landscape. The Delta today is a highly modified system of artificial levees and dredged waterways that were constructed to control flooding and to support farming and urban development on reclaimed islands (Ingebritsen et al. 2000). The peat soils that developed over thousands of years have been largely drained. This practice resulted in rapid biological oxidation of organic matter in peat soils and large-scale land subsidence on Delta islands (Ingebritsen et al. 2000; Deverel and Rojstaczer 1996), such that there are currently substantial areas with land surface elevations below sea level.

Soils continue to be a key resource in the Delta (Delta Protection Commission 1993) and have physical and chemical characteristics that qualify them as prime farmland (CALFED 2000, Ch. 5). The growing season, drainage, and available moisture in Delta soils provide an excellent medium for growing a wide variety of crops of economic importance. The soil conditions also continue to support important marshland ecosystems in the Delta and the Suisun Marsh.

11.4.2.1 Soil Associations

Maps of soils are created by the NRCS, an agency within the U.S. Department of Agriculture. These maps include detailed information about soils, their physical and chemical characteristics, and suitability for a variety of uses. Because of the broad geographical scale of this project, soil associations were used for the soil analysis.

Soil associations are groupings of individual soils that occur together in the landscape and are typically named after the two or three dominant soil series (e.g., the dominant soil components in the Gazwell-Rindge soil association in Sacramento County are the Gazwell and Rindge soil series).

Associations cover broad areas within the landscape that have a distinctive pattern of soils, relief, and drainage. Figure 11-6 shows soil associations located within the project area.

Within the Delta and Suisun Marsh, soils can be generally classified based on the following physiographic positions and features:

- Basins, delta, and saltwater marsh
- Basin rims
- Floodplains and stream terraces
- Valley fill, alluvial fans, and low terraces
- Uplands and high terraces

11.4.2.1.1 Basin, Delta, and Saltwater Marsh Soils

Basin, Delta, and Saltwater Marsh soils occupy the lowest elevation ranges and are often protected by levees (Soil Conservation Service [SCS] 1993a, 1993b). Most of these low-lying soils contain substantial organic matter and are classified as peats or mucks (SCS 1993a, 1993b). Examples of soil associations in the Delta that contain substantial amounts of organic matter include the Gazwell-Rindge association in Sacramento County, the Rindge-Kingile-Ryde and Peltier-Egbert associations in San Joaquin County, and the Rindge-Kingile and Joice-Reyes associations in Contra Costa County (Figure 11-6).

Soils in outer portions of the basin contain more mineral material and less organic material than those in the central Delta. Mineral soils that occur in some portions of the Delta are typically fine textured with poor drainage (e.g., the Clear Lake association in Sacramento County, the Sacramento association in Yolo County, and the Sacramento-Omni association in Contra Costa County). These soils also may be calcareous with high salinity and sodium contents (e.g., the Willows-Pescadero association in Yolo and San Joaquin counties).

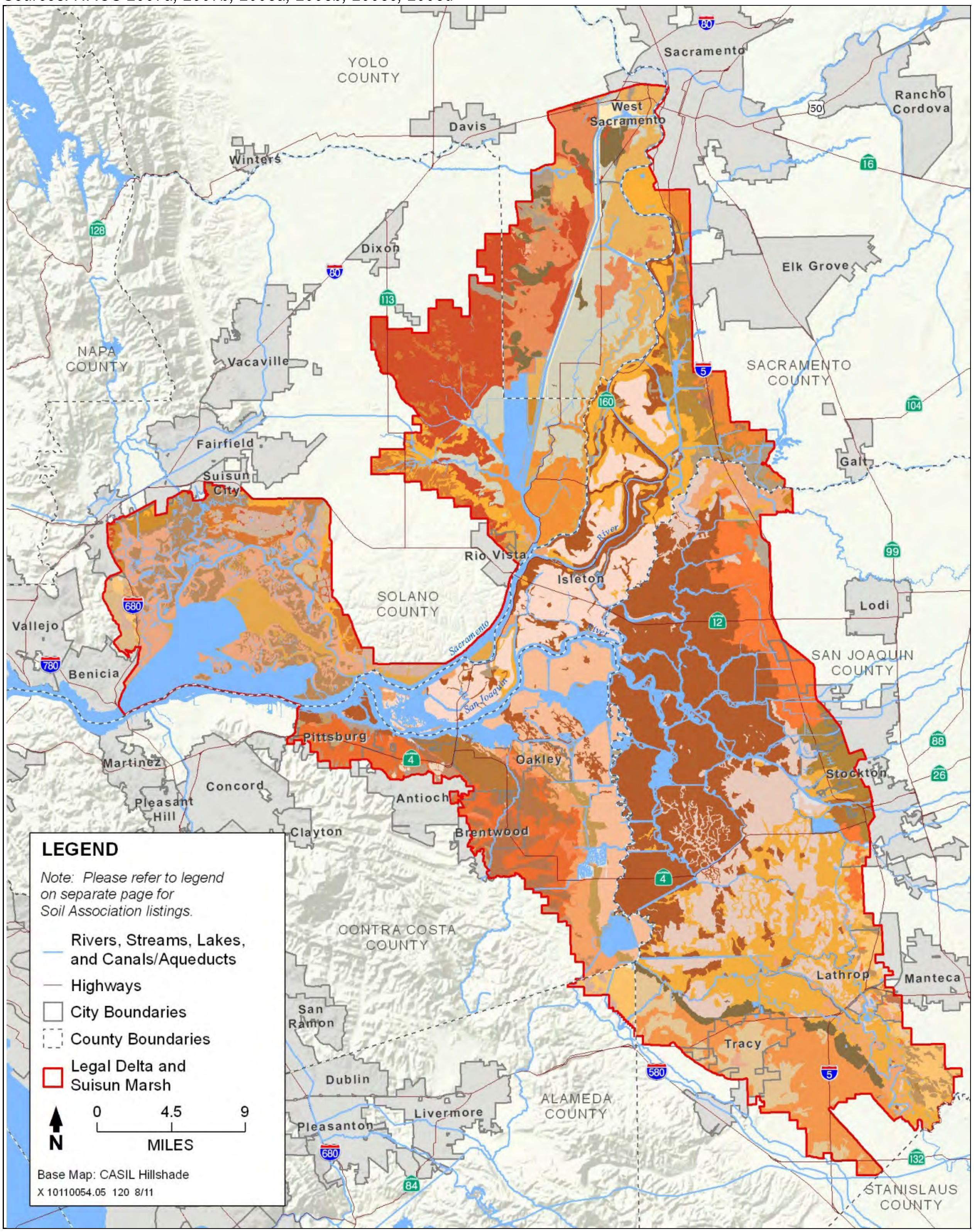
11.4.2.1.2 Basin Rim Soils

Basin rim soils are found along the rims (edges) of basins. Soils in this physiographic position are generally moderately deep or deep mineral soils that are poorly drained to well-drained, and have fine textures in surface horizons. Some areas contain soils with a hardpan layer in the subsurface. For example, the Marcuse-Solano-Pescadero association in Contra Costa County contains very poorly drained to somewhat poorly drained clays, loams, and clay loams (Figure 11-6). A cemented hardpan can occur at depths of 40 to 60 inches in Hollenbeck soils in San Joaquin County. Dierssen soils in western Sacramento County have a sandy clay loam texture at the surface, calcareous clay subsoil, and a hardpan at a depth of 20 to 45 inches, and also can have a perched water table at a depth of 6 to 36 inches in winter and early spring (SCS 1993a).

11.4.2.1.3 Floodplain and Stream Terrace Soils

Floodplain and stream terrace soils are mineral soils adjacent to major rivers and other streams, and may be associated with landward sediment accumulations behind natural levees. Soils are typically deep and stratified, with relatively poor drainage and fine textures. Examples include Sailboat-Scribner-Cosumnes and Egbert-Valpac associations adjacent to the Sacramento River, and the Columbia-Cosumnes association adjacent to the Cosumnes River and other streams in Sacramento County (Figure 11-6). The Merritt-Grangeville-Columbia and Columbia-Vina-Coyote creek associations in San Joaquin County are additional examples.

Figure 11-6
Soil Associations for the Delta and Suisun Marsh
Sources: NRCS 2007a, 2007b, 2008a, 2008b, 2008c, 2008d



LEGEND

Soil Associations

Alameda County
1 - Altamont-Diablo association
6 - Clear Lake-Sunnyvale association
7 - Rincon-San Ysidro association
Water

Contra Costa County
1 - Brentwood-Rincon-Zamora association
2 - Capay-Sycamore-Brentwood association
3 - Capay-Rincon association
4 - Delhi association
5 - Clear Lake-Cropley association
6 - Marcuse-Solano-Pescadero association
7 - Rindge-Kingile association
8 - Sacramento-Omni association
9 - Joice-Reyes association
10 - Tierra-Antioch-Perkins association
11 - Altamont-Diablo-Fontana association
12 - Los Osos-Millsholm-Los Gatos association
Urban
Water

Sacramento County
1 - Xerorthents association
2 - Gazwell-Rindge association
3 - Sailboat-Scribner-Cosumnes association
4 - Egbert-Valpac association
5 - Columbia-Cosumnes association
8 - Clear Lake association
9 - Dierssen association
10 - San Joaquin association
Urban
Water

San Joaquin County
1 - Rindge-Kingile-Ryde association
2 - Peltier-Egbert association
3 - Merritt-Grangeville-Columbia association
4 - Columbia-Vina-Coyotecreek association
5 - Willows-Pescadero association
6 - Jacktone-Hollenbeck-Stockton association
7 - Guard-Devries-Rioblancho association
8 - Capay association
9 - Capay-Stomar-Zacharias association
10 - Delhi-Veritas-Tinnin association
11 - Archerdale-Cogna-Finrod association
12 - Tokay-Acampo association
13 - Madera association
14 - San Joaquin-Bruella association
15 - Carbona-Pleito association
18 - Redding-Yellowlark association
Urban
Water

Solano County
1 - Yolo-Brentwood association
2 - Yolo-Sycamore association
3 - Rincon-Yolo association
4 - Capay-Clear Lake association
5 - Sacramento association
6 - Egbert-Ryde association
7 - Valdez association
8 - Joice-Suisun association
9 - Reyes-Tamba association
10 - San Ysidro-Antioch association
12 - Solano-Pescadero association
13 - Altamont-Diablo association
14 - Dibble-Los Osos association
15 - Millsholm association
17 - Hambright-Toomes association
Quarries
Water

Yolo County
1 - Yolo-Brentwood association
2 - Rincon-Marvin-Tehama association
3 - Capay-Clear Lake association
4 - Sycamore-Tyndall association
5 - Sacramento association
6 - Willows-Pescadero association
7 - Capay-Sacramento association
8 - Corning-Hillgate association
Made Land
Water

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11.4.2.1.4 Valley Fill, Alluvial Fan, and Low Terrace Soils

Valley fill, alluvial fan, and low terrace soils are typically very deep with variable texture and ability to transmit water. Valley fill and alluvial fan soils range from somewhat poorly drained fine sandy loams and silty clay loams to well-drained silt loams and silty clay loams (e.g., the Sycamore-Tyndall and Yolo-Brentwood associations in Yolo County). Soils on low terraces tend to be moderately well-drained with a claypan subsoil and may have a cemented hardpan at depth (San Joaquin association in Sacramento County and San Joaquin-Bruella and Madera soils in San Joaquin County). A perched water table may be present as the result of irrigation (e.g., the Capay-Sycamore-Brentwood association in Contra Costa County [SCS 1977a] and the Capay association on interfan basins of San Joaquin County [SCS 1993b]).

11.4.2.1.5 Upland and High Terrace Soils

Upland and high terrace soils are generally well-drained and range in texture from loams to clays. These soils primarily formed in material weathered from sandstone, shale, and siltstone, and can occur on dissected terraces (e.g., Altamont-Diablo association in Solano and Alameda counties) or on mountainous uplands (Dibble-Los Osos and Millsholm associations in Solano County [SCS 1977b]). Erosion by surface water flows may be a hazard where slopes are steep. There may be slow permeability in the subsoil (e.g., Corning-Hillgate association in Yolo County) or a cemented hardpan at depth (Redding-Yellowlark soils in San Joaquin County).

11.4.2.2 Soil Properties and Characteristics

Soil physical and chemical characteristics affect the way a soil “behaves” under specific land uses. These characteristics are especially important for engineering uses. Relevant soil physical and chemical properties described in this section include expansiveness (i.e., shrink-swell capacity), and erodibility by water and wind.

11.4.2.2.1 Expansive Soils (Shrink-Swell Capacity)

Expansive soils increase in volume when wet and shrink in volume when dry. The degree of expansiveness, or shrink-swell capacity, depends on the type and amount of clay in the soil, and is determined by measuring the linear extensibility percent (LEP) of a soil. LEP is related to the volume difference of a soil at a particular water content and at oven dryness. Large portions of the northern and southwestern parts of the Delta, and areas within the Suisun Marsh Areas have the highest shrink-swell capacity, while soils with the lowest shrink-swell capacity occur in the central and southeastern parts of the Delta (Figure 11-7).

11.4.2.2.2 Soil Erodibility by Water

Water erosion occurs when raindrop impact detaches soil particles, and flowing water removes and transports soil material. Sheet erosion removes soil from an area in a fairly uniform manner without development of discrete channels. Rill erosion removes soil through the cutting of many small but discrete channels where runoff concentrates. Gully erosion occurs when water cuts down into the soil along the line of flow, and the cut channels are deep enough that they cannot be obliterated through tillage.

Figure 11-7
Potential for Linear Extensibility
Source: NRCS 2010a

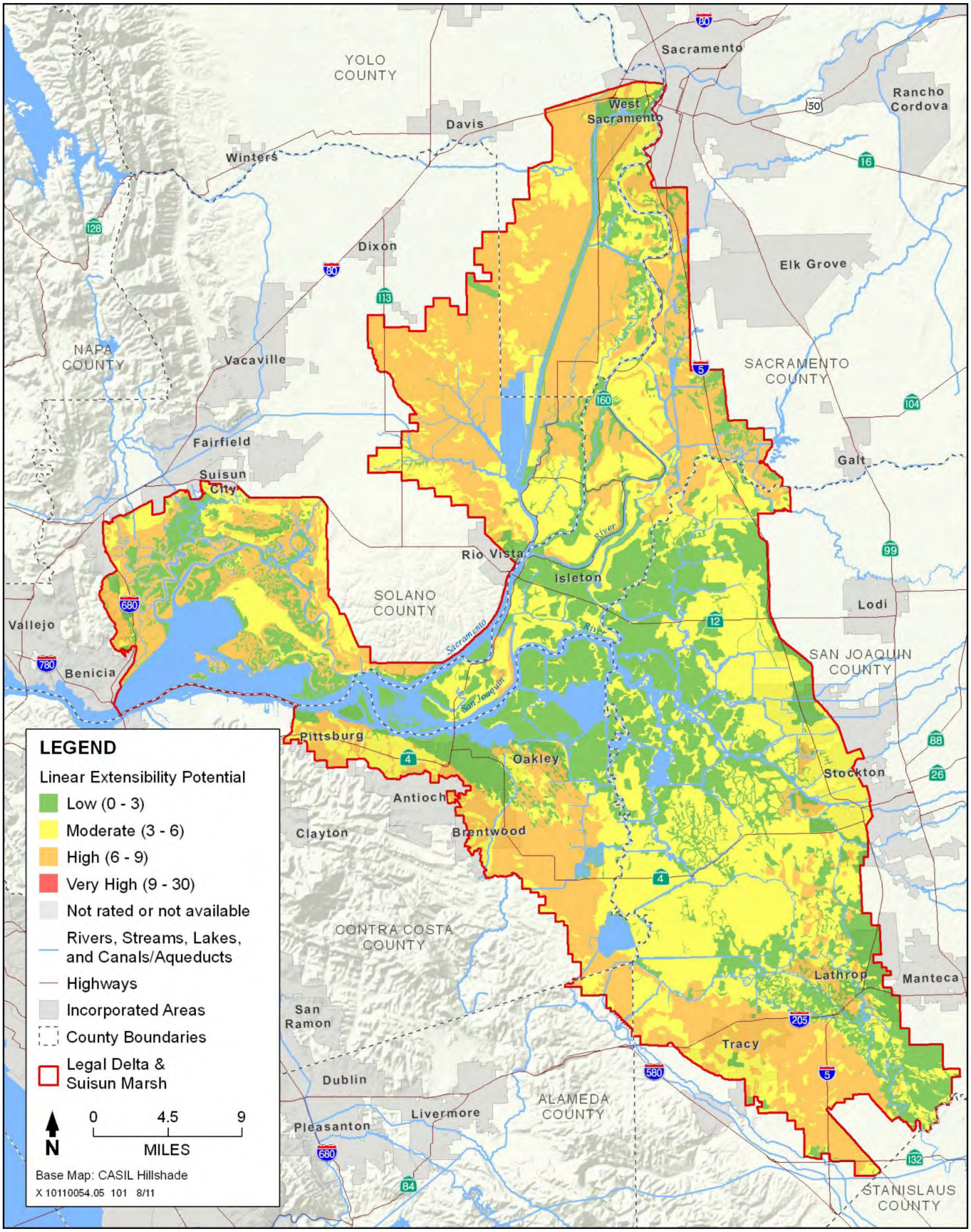


Figure 11-8 provides water erosion hazard ratings for soils in the Delta and Suisun Marsh (NRCS 2010b). These soil survey hazard ratings are based on sheet or rill erosion in areas outside of roads and trail areas, where 50 to 75 percent of the land surface has been exposed by ground-disturbing activities. Hazard ratings range from “slight,” which indicates that erosion is unlikely under ordinary climatic conditions, to “very severe,” which indicates that significant erosion is expected, loss of soil productivity and offsite damage are likely, and erosion-control measures are costly and generally impracticable (NRCS 2010c). The ratings are representative of the water erosion hazard that would exist during construction or other ground-disturbing activities. The water erosion hazard ratings are based on the dominant soil present, although other, minor soil components also may be present within the map unit. Water erosion hazard is rated as very severe in the central Delta where highly organic soils are present; elsewhere in the Delta and in portions of Suisun Marsh, water erosion hazard is primarily slight.

11.4.2.2.3 Soil Erodibility by Wind

Soil erodibility by wind is related to soil texture, organic matter content, calcium carbonate content, rock fragment content, mineralogy, and moisture content. NRCS assigns soil map units into one of eight wind erodibility groups (WEG) based on potential susceptibility to blowing (NRCS 2010c), with 1 being most susceptible to wind erosion, and 8 being the least susceptible. In addition to having a very severe water erodibility hazard rating, the highly organic soils of the Suisun Marsh and the central Delta also have a high susceptibility to wind erosion, as indicated by their classification in WEGs 1 through 3 (Figure 11-9).

11.4.3 Other Areas of California

As described in Section 2A, Proposed Project and Alternatives, facilities could be constructed, modified, or reoperated, not only in the Delta, but in other areas of the Delta watershed and areas outside of the Delta that use Delta water. Because these areas outside the Delta may experience different climate, topography, biological activity, land uses, and parent material compared to the Delta, soils of these areas may have different physical and chemical characteristics than Delta soils. Landforms in the Delta watershed and areas outside of the Delta that use Delta water include floodplains, basin rim/valley floor, terraces, foothills/mountains (CALFED 2000). Alluvial floodplain soils associated with rivers and streams are often very fertile and used for crop production. In the San Joaquin Valley, basin soils are fine textured, and may have poor drainage and a high water table. At higher elevations, mountains with steep slopes are present and bedrock may underlie shallow soils. In addition, areas outside of the Delta that use Delta water include coastal regions in Central and Southern California. Soils in these areas may be associated with heavily urbanized environments or sensitive coastal and estuarine ecosystems.

11.5 Impacts Analysis of Project and Alternatives

11.5.1 Assessment Methods

The Proposed Project (Delta Plan) and alternatives would not directly result in construction or operation of projects or facilities, and therefore would result in no direct geology- or soil-related impacts.

Figure 11-8
Soil Erosion Potential – Water
Source: NRCS 2010b

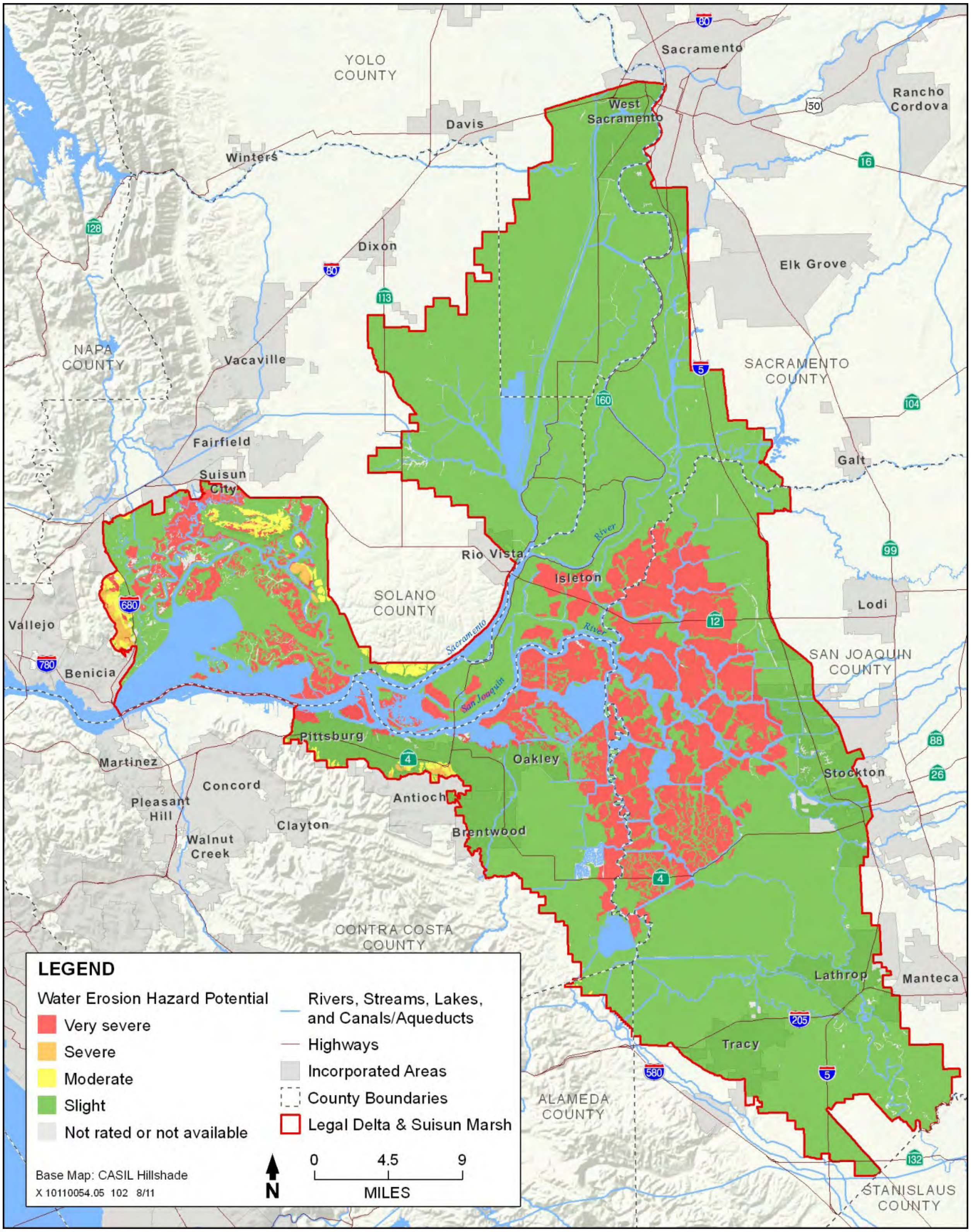
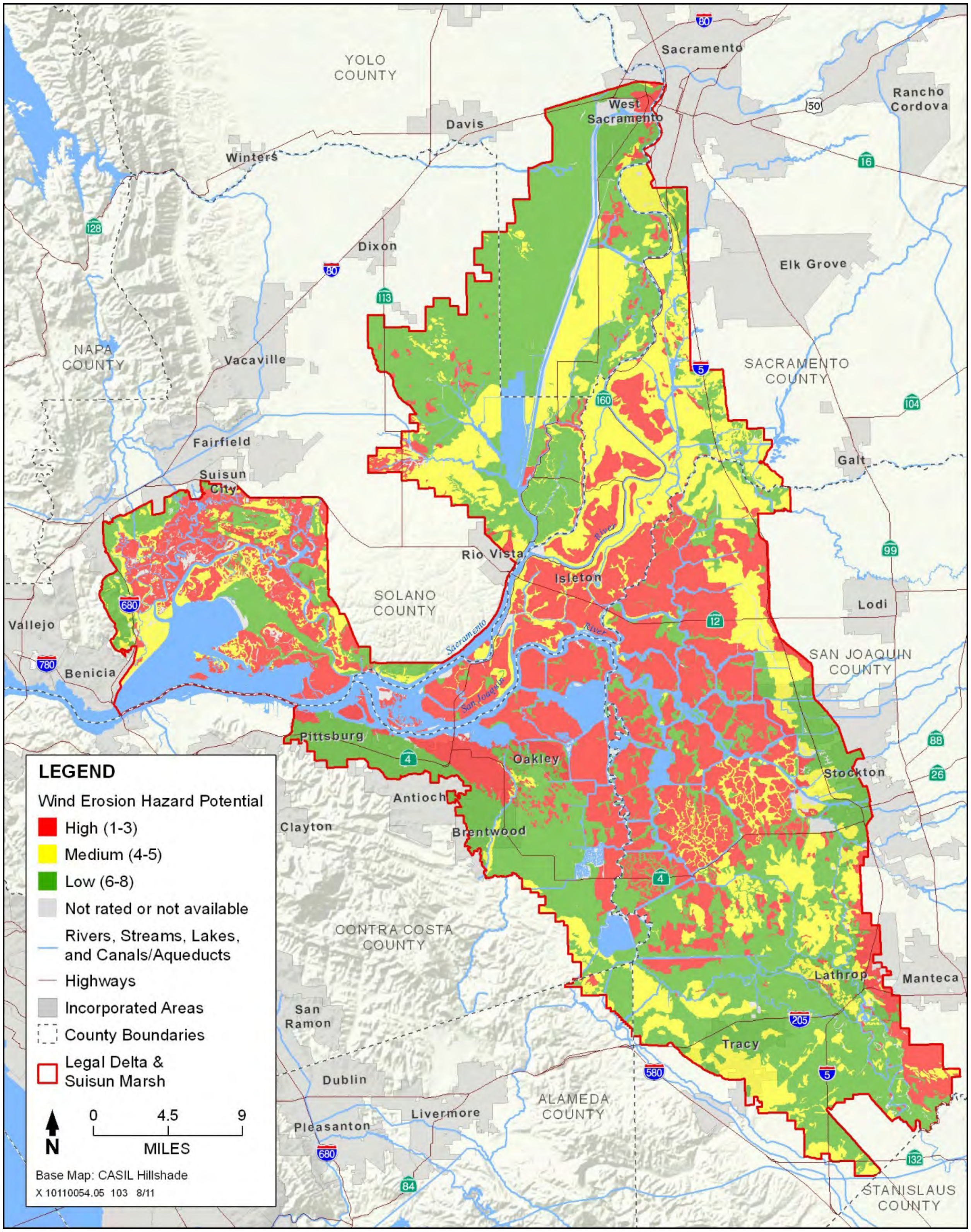


Figure 11-9
Soil Erosion Potential – Wind
Source: NRCS 2010c



The Delta Plan and alternatives could encourage the implementation of actions or activities by other agencies to construct and operate facilities or infrastructure that are described in Sections 2A and 2B. Examples of potential actions include land use changes, conversion of agricultural lands, or land fallowing. Projects may include construction of water and wastewater treatment plants; conveyance facilities, including pumping plants; surface water or groundwater storage facilities; ecosystem restoration projects; flood control levees; or recreation facilities. Implementation of these types of actions and construction and operation of these types of facilities could result in local subsidence due to loading of existing underlying sediments, exposure to seismic shaking or fault rupture; exposure to hazards associated with expansive soils; and erosion or loss of topsoil.

The precise magnitude and extent of project-specific geology- and soil-related impacts would depend on the type of action or project being evaluated, its specific location, its total size, and a variety of project- and site-specific factors that are undefined at the time of preparation of this program-level EIR. Project-specific geology- and soil-related impacts would be addressed in project-specific environmental studies conducted by the lead agency at the time the projects are proposed for approval.

Geology-related impacts from implementation of the Delta Plan alternatives were evaluated in terms of how project components could cause subsidence and exposure to seismic shaking or fault rupture hazards. Loss of mineral resources is discussed in Section 13 (Mineral Resources). Because project-level construction disturbance details are not available for the project components analyzed, potential geology-related impacts were evaluated for construction in many areas of California.

Impacts on soil resources from implementation of the Delta Plan alternatives were evaluated qualitatively in terms of the potential for construction, operation, and/or restoration activities to adversely affect soil resources; and the degree to which soil expansiveness may affect Proposed Project features. Because project-level construction, operation, and restoration details are not available, potential effects related to soils were evaluated qualitatively for these activities in the Delta, the Delta watershed and in other regions of the state that receive Delta exports. Impacts are discussed less specifically for the Delta watershed and for other regions of the state that use Delta water, compared to impacts in the Delta and Suisun Marsh.

This EIR proposes mitigation measures for geology-related impacts. The ability of these measures to reduce impacts to less-than-significant levels depends on project-specific environmental studies; enforceability of these measures depends on whether or not the project being proposed is a covered action. This is discussed in more detail in Section 11.5.3.6 and in Section 2B, Introduction to Resource Sections.

11.5.2 Thresholds of Significance

Based on Appendix G of the California Environmental Quality Act (CEQA) Guidelines, an impact related to geology is considered significant if the Proposed Project would do any of the following:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault; refer to Division of Mines and Geology Special Publication 42.
  - Strong seismic ground shaking
  - Seismic-related ground failure, including liquefaction
  - Landslides

- Result in substantial soil erosion or the loss of topsoil
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (UBC) (1994), creating substantial risks to life or property
- Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

The following discussion of environmental impacts is limited to those potential impacts that could result from actions or projects the Delta Plan alternatives could encourage. As individual activities are proposed by other agencies, these individual activities will need to be evaluated in site-specific environmental documents prepared by those agencies.

The impact analysis for the Proposed Project was structured to allow more detailed analysis of impacts as they relate to the Delta Plan policy elements (Reliable Water Supply, Delta Ecosystem Restoration, Water Quality Improvement, Flood Risk Reduction, Protection and Enhancement of Delta as Evolving Place). To avoid unnecessary repetition in the analysis of impacts that could occur under the alternatives to the Proposed Project, each impact is discussed only once for each alternative.

11.5.3 Proposed Project

11.5.3.1 Reliable Water Supply

As described in Sections 2A and 2B, the Delta Plan does not direct the construction of specific projects, nor would projects be implemented under the direct authority of the Delta Stewardship Council. However, the Delta Plan seeks to improve water supply reliability by encouraging various actions, which if taken could lead to completion, construction and/or operation of projects that could provide a more reliable water supply. Such projects and their features could include the following:

- Surface water projects (water intakes, treatment and conveyance facilities, reservoirs)
- Groundwater projects (wells, wellhead treatment, conveyance facilities)
- Ocean desalination projects (water intakes, brine outfalls, treatment and conveyance facilities)
- Recycled wastewater and stormwater projects (treatment and conveyance facilities)
- Water transfers
- Water use efficiency and conservation program implementation
- Hydroelectric generation (e.g., powerhouse, transmission lines)

The number and location of all potential projects that would be implemented is not known at this time. Three possible projects, however, are known to some degree and are named in the Delta Plan: these projects are the subjects of the North of Delta Offstream Storage Investigation (aka Sites Reservoir), Los Vaqueros Reservoir Project (Phase 2), and Upper San Joaquin River Basin Storage Investigation Plan (aka Temperance Flat) (collectively known as the DWR Surface Water Investigation). It also encourages the update of Bulletin 118, DWR’s comprehensive groundwater report, which could lead to improvements in groundwater management and development of related facilities. Bulletin 118 presents a list of 10 recommendations for the management of groundwater but does not result in construction or operation of a specific project which could have geology- or soil-related impacts; therefore, Bulletin 118 is not evaluated in this section.

Actions to enhance water supply reliability could include water transfers and modified reservoir operations. Water transferred from north of the Delta could result in a temporary increase in water in the rivers flowing into the Delta. Changes in water operations in the Central Valley Project and State Water

Project and other water systems also could alter the timing and magnitude of water fluctuations in the upstream reservoirs. Other programs intended to improve water supply reliability, such as water conservation, could result in more water remaining in the rivers tributary to the Delta and less water removed from the Delta. None of these flow-related changes due to water transfers and modified operations would require construction or operation of new facilities. Therefore, these types of actions are not likely to have impacts related to geology and are not evaluated in the following impact sections.

11.5.3.1.1 Impact 11-1a: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

Construction of facilities associated with surface water and groundwater projects (including those that could be encouraged through the update of Bulletin 118), ocean desalination projects, and recycled wastewater and stormwater projects could result in exposure of people or structures to adverse effects involving the rupture of known earthquake faults. These facilities could be constructed in the Delta, in the Delta watershed, or in areas outside the Delta that use Delta water, as described in Section 2A, Proposed Project and Alternatives. Once constructed, operation of these facilities would continue to expose people and structures to earthquake hazards.

The Davis-Woodland Water Supply Project EIR (City of Davis et al. 2007) was reviewed to assess the types of effects that could result from installing a new water intake and constructing pumping plants and conveyance and water treatment facilities. This project is analogous to the types of water projects described above. In this EIR, the City evaluated the potential for the project to expose people or structures to substantial adverse effects, including the risk of loss, injury, or death involving rupture of a known earthquake fault and found that the impact would be less than significant after mitigation. The Draft Recirculated EIR for the Seawater Desalination Project (City of Huntington Beach 2010), which illustrates some the likely impacts of ocean desalination plants, also was reviewed. For this project, the City found that although the project is located within 1.25 miles of an Alquist-Priolo earthquake fault zone, geologic impacts could be mitigated to less than significant levels.

The large surface storage reservoirs encouraged by the Proposed Project also could result in the exposure of people or structures to adverse effects involving the rupture of known earthquake faults. The impacts of these types of projects would depend on the ultimate location of the reservoirs and their proximity to known earthquake faults. These projects would occur mostly outside of the Delta.

Of the three large surface storage reservoirs considered by the DWR Surface Water Storage Investigation, only the Los Vaqueros Reservoir Expansion Project has undergone project-specific environmental review via an Environmental Impact Statement (EIS)/EIR (U.S. Bureau of Reclamation [Reclamation] et al. 2009); the other two projects have not. The Los Vaqueros EIS/EIR provides specific information on the impacts of that project; however, it also provides analogous information about the types of impacts expected from construction and operation of these two other projects, which are similar. In addition, the project-specific EIR for another surface storage project (not named in the Delta Plan) – the Calaveras Dam Replacement Project – also provides analogous information.

The Los Vaqueros Reservoir Expansion EIS/EIR evaluated several alternatives to increase water storage, some of which included a new Delta intake structure, and conveyance facilities. The lead agency found that project facilities would be designed and engineered in accordance with seismic code requirements. As a result, the project would not expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking or seismic-related ground failure, including liquefaction and landslides. Therefore, this impact was considered less than significant and no mitigation measures were required. The San Francisco Public Utilities Commission (SFPUC) found in its final EIR for the Calaveras Dam Replacement Project, a project analogous to surface storage projects that may be implemented under the Delta Plan, found that surface fault rupture impacts could be mitigated to less-than-significant levels (SFPUC 2011).

Two known earthquake faults with surface expression cross the project area, the Concord fault and the Pittsburgh-Kirby Hills fault (see Figure 11-1). Both of these faults are strike-slip faults, having modeled maximum earthquake moment magnitudes of 6.7. Presence of these faults within the Alquist-Priolo Special Studies Zones, as delineated by the State Geologist, may impact construction activities. Structures intended for human occupancy cannot be constructed astride the surface traces of active faults in California. Structural setbacks may therefore be required where active fault traces are present. Special design considerations may also be required in proximity to these faults to mitigate potential high ground acceleration. It should be noted that other active faults are present at depth within the Project Area. These are known as blind thrust faults, and they have no surface expression. Potential impacts associated with these blind thrust faults do not include surface rupture, but are instead limited to strong ground motion, and are discussed in Section 11.5.3.1.2.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects and projects encouraged by the Proposed Project to be located on a known earthquake fault, this potential impact is considered **significant**.

11.5.3.1.2 Impact 11-2a: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

Projects to improve water supply reliability, such as the North Bay Aqueduct Alternative Intake project identified in the Delta Plan (Proposed Project), could include water intakes, pumping plants, sedimentation basins, treatment, and associated conveyance facilities (e.g., pipelines and canals). These types of projects could be constructed in the Delta, Delta watershed, and in areas outside the Delta that receive Delta water. Construction of facilities could result in exposure of people or structures to adverse effects involving the rupture of known earthquake faults. Operation of these facilities would continue to expose people and structures to earthquake hazards.

Due to the presence of nearby faults, including: a) known active faults within the Project Area that have surface expression (discussed in Section 11.5.3.1.1); b) known active faults within the Project Area that do not have surface expression (such as the Midland and Vernalis blind thrust faults); and c) known regional active faults in the vicinity of the project area that have or do not have surface expression, strong ground motion during seismic events can and will occur within the Project Area in the future. The effects of strong ground motion (shaking) are many, among which the most significant are direct structural deformation and failure of inhabited structures, ground failure beneath inhabited structures, or ground failure beneath critical infrastructure such as dams and levees. Other, less significant effects can include damage to uninhabited structures, pipelines, canals, and other constructed improvements.

The Davis-Woodland Water Supply Project EIR (City of Davis et al. 2007) was reviewed to assess the types of effects that could result from installing new water intakes and constructing pumping plants and conveyance and water treatment facilities. In this EIR, the City evaluated the potential for the project to expose people or structures to substantial adverse effects involving strong seismic ground shaking and found that the impact would be significant. Mitigation measures including conduct of a detailed geotechnical study of the project area that includes the liquefaction potential, bearing strength of soils and levee slope stability and incorporating the findings of the study into facility design would reduce this impact to less than significant after mitigation.

Small storage reservoirs, regulating reservoirs, and groundwater percolation basins that might be constructed to improve water supply reliability throughout the Study Area could expose people or structures to adverse effects involving strong seismic ground shaking. The extent of impact would be influenced by the size of the facility footprint and its location relative to areas of seismic disturbance.

Construction of large surface water storage reservoirs such as those considered in DWR's Surface Water Storage Investigation (Sites, Los Vaqueros, and Temperance Flat reservoirs) also could result in the exposure of people or structures to adverse effects involving seismic ground shaking. The impacts of these types of projects would depend on the ultimate location of the reservoirs and their proximity to areas of seismic disturbance. These projects would occur mostly outside of the Delta. The Los Vaqueros Reservoir Expansion Project and Calaveras Dam Replacement Project illustrate some of the types of geologic impacts associated with surface water storage projects.

In the EIS/EIR for the Los Vaqueros Reservoir Expansion Project (Reclamation et al. 2009), the lead agency found that project facilities would be designed and engineered in accordance with seismic code requirements. As a result, the project would not expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking or seismic-related ground failure, including liquefaction and landslides. Therefore, this impact was considered less than significant and no mitigation measures were required.

In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency found that hazards of seismically induced ground failure, including liquefaction, lateral spreading, and settlement at disposal fill sites would be significant. Mitigation measures included conducting a detailed geotechnical evaluation if fill placement creates final slopes greater than 20 feet high. The analysis would address static stability, hazards from fault offset, drainage, erosion control, and grading requirements. Ensuring that all measures specified for design and construction of the fills are implemented by the construction contractor would reduce this impact to less than significant after mitigation.

Ocean desalination plants might be constructed and operated outside the Delta to increase water supply. The construction of these facilities would have impacts similar to those described above for construction of water intakes, pumping plants, and associated conveyance facilities. The Draft Recirculated EIR for the Seawater Desalination Project at Huntington Beach (City of Huntington Beach 2010) found that the project site's high liquefaction potential and shallow groundwater conditions may create significant geologic hazards. However, mitigation measures such as preparation of a detailed geotechnical report that specifically addresses lateral spreading, flood control channel bank stability, liquefaction potential, and groundwater constraints, would reduce this impact to less than significant levels.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects and projects encouraged by the Proposed Project to be located in areas where strong ground motion during seismic events can and will occur, this potential impact is considered **significant**.

11.5.3.1.3 Impact 11-3a: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil That Is Unstable, or That Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction or Collapse

Construction-related activities for the types of projects identified in 11.5.3.1 could require the use of heavy equipment, such as excavators, graders, scrapers, bulldozers, backhoes, and concrete mixing and pumping trucks, along with haul trucks that would be used to move borrow and/or spoils and other materials. In areas of unstable soils, with the potential for lateral spreading, subsidence, liquefaction or collapse, heavy and/or tall equipment could sink, tip over and/or be difficult to handle (driving or moving controls) causing unsafe working conditions. Construction activities for intakes, sedimentation basins, pumping plants, pipelines and forebays could occur in areas underlain by soft or loose soils, where high groundwater or seepage may be present and on sloping ground.

Construction-related modifications of existing delta fluvial sediments, peats, and topsoils arising from grading required for development of various projects may result in a reduction of stability. Surcharging loads arising from placement of fill to locally raise grades may accelerate subsidence by causing consolidation of the peat and other unconsolidated sediments. Collapse of pore space in peat layers is the chief concern, but consolidation by compaction of saturated silts and sands is also a potential impact. Subsidence, particularly differential subsidence occurring after construction, can also result in distress to improvements.

Where existing surficial layers are removed by grading, such as during construction of a new canal, potentially liquefiable sands may be exposed which increased the risk of loss of bearing value, soil settlement and lateral spreading during fault rupture-related seismic shaking events where transient higher pore-water pressures in groundwater cause the soil to liquefy. Repeated trips of loaded haul trucks on paved roads situated on top of shallow saturated sediments may also result in liquefaction and resultant deformational damage to roadbeds.

The operation of canals, pipelines, tunnels, siphons, pumping plants and groundwater wells in areas of unstable soils, and with the potential for lateral spreading, subsidence, liquefaction, or collapse, could be disrupted for several reasons including roadway collapse, differential subsidence and compaction, pipe breaking or collapse. Where groundwater well fields are planned, potential subsidence could encompass the entire well field.

Operation of surface water storage facilities and canals may result in leakage to the subsurface, possibly resulting in expansion of clayey sediments at shallow depths beneath the reservoirs or canals (see Section 11.5.3.1.5). Operation of surface water storage facilities and canals also may result in the occurrence of nuisance water (formation of surface springs and seeps) in adjacent areas due to leakage of such facilities during operation (see Section 11.5.3.1.6).

In the EIS/ EIR for the Los Vaqueros Reservoir Expansion Project (Reclamation et al. 2009), the lead agency found that some project components could be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities. However, those components would not likely result in onsite or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse because proposed actions would require the preparation of a site-specific geotechnical investigation which would identify potential geologic hazards such as landslides, subsidence, and expansive/corrosive soils. Proposed improvements would be constructed according to industry standard practices and Contra Costa Water District (CCWD) construction standards. Therefore, this impact was considered less than significant.

In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency found that impacts related to soil or geologic unit instability would be significant. Mitigation measures included conducting a detailed geotechnical evaluation if fill placement creates final slopes greater than 20 feet high. The analysis would address static stability, hazards from fault offset, drainage, erosion control, and grading requirements. Ensuring that all measures specified for design and construction of the fills are implemented by the construction contractor would reduce this impact to less than significant after mitigation.

The Delta Plan encourages other types of water supply projects, such as ocean desalination plants. The Delta Plan does not name any particular project, but a desalination project is contemplated in Huntington Beach is typical. The Draft Recirculated EIR for the Seawater Desalination Project (City of Huntington Beach 2010) found that the project would be subject to seismically induced settlement and lateral spread as the project area has a high potential for liquefaction. This impact was considered significant but could be mitigated to a less than significant level through preparation of a detailed geotechnical report that specifically addresses lateral spreading, flood control channel bank stability, liquefaction potential, and groundwater constraints and compliance with the standards set forth in California Geological Survey Special Publication 117 (CGS 1997).

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. Geotechnical investigations would be conducted during design at and near the locations of facilities to the depths necessary to characterize the subsurface conditions. The information would be used to determine foundation criteria that meet the settlement and bearing-capacity requirements for structures. However, because of the potential for facilities constructed as a result of named projects and projects encouraged by the Proposed Project to be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities, this potential impact is considered **significant**.

11.5.3.1.4 Impact 11-4a: Construction of Projects Could Result in Substantial Soil Erosion or the Loss of Topsoil

Construction-related activities for the types of projects identified in Section 11.5.3.1 would disturb large volumes of soil through excavating, earth moving, grading, filling, and stockpiling of soil material, and these disturbed soils could be susceptible to wind and water erosion. Without implementation of appropriate management measures, substantial erosion and loss of topsoil could occur.

Any construction project more than 1 acre in size would be required to comply with the California General Permit for Stormwater Discharges Associated with Construction and Land Disturbance Activities (General Permit), State Water Resources Control Board (SWRCB) Order No. 2009-0009-DWQ. This permit requires development and implementation of an effective combination of erosion and sediment control best management practices (BMP) to manage erosion and topsoil loss. Construction and post-construction BMPs would be identified in the project’s Stormwater Pollution Prevention Plan (SWPPP).

It is unclear at this time how implementation of the Proposed Project would result in specific construction activities, including the location, number, capacity, and methods and duration of construction activities. However, the Delta Plan encourages, at least to some degree, implementation of the North of Delta Offstream Storage Investigation, Los Vaqueros Reservoir Project (Phase 2), and the Upper San Joaquin River Basin Storage Investigation Plan. These are possible new or expanded surface water storage facilities.

The Los Vaqueros Project has undergone project-specific environmental review via an EIS/EIR; the other two projects have not. The Los Vaqueros EIS/EIR, however, provides analogous information about the impacts expected from construction of the two other projects, which are similar to the Los Vaqueros Project. In addition, the project-specific EIR for another surface storage project (not named in the Delta Plan)—the Calaveras Dam Replacement Project—also provides analogous information.

In the EIS/EIR for the Los Vaqueros Reservoir Expansion Project (Reclamation et al. 2009), the lead agency found that while construction of the project would disturb large volumes of soil, implementation of a SWPPP would reduce impacts to a less than significant level. In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency did not identify any impacts associated with the loss of topsoil, but did identify a significant impact on water bodies as a result of soil erosion and sediment discharge during construction. This impact could be mitigated to a less than significant level through implementation of a project-specific SWPPP approved by the San Francisco Bay Regional Water Quality Control Board (RWQCB).

Although not named in the Delta Plan, the following projects, based on a review of their project-specific EIRs, are illustrative of the types of construction-related impacts on soils associated with water supply reliability projects: the Davis-Woodland Water Supply Project (City of Davis et al. 2007), which includes a water intake in the Sacramento River, pumping plants, and conveyance and water treatment facilities; and the Carlsbad Precise Development Plan and Desalination Plant Project EIR (City of Carlsbad 2005), which illustrates some of the likely impacts of constructing a seawater desalination plant. The City of Davis found that the project could result in substantial soil erosion or the loss of topsoil, but that impacts would be less than significant with mitigation that included preparation and implementation of a SWPPP and various BMPs. The City of Carlsbad found that construction activities, especially earth movement and disturbance, would lead to soil erosion. Impacts from these activities were considered mitigated to a less than significant level by implementation of construction BMPs and implementation of an approved SWPPP.

Because water supply reliability projects and actions encouraged by the Delta Plan would be required to comply with local requirements and State regulations, and would develop and implement a site-specific SWPPP, soil erosion and topsoil loss would likely be minimized. The details of many of the aspects of these projects, however, are not currently known, and it is possible that significant soils loss could occur. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies of these potential projects. However, because of the potential for substantial soil erosion or loss of topsoil as a result of named projects and projects encouraged by the Proposed Project, this potential impact is considered **significant**.

11.5.3.1.5 Impact 11-5a: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

Expansive soils shrink and swell with wetting and drying cycles in the soil, creating an unstable foundation for rigid structures. Construction-related grading activities for the types of projects identified in Section 11.5.3.1 could expose or reduce the vertical distance to expansive clays in the subsurface, exacerbating the problem. Expansive clays can cause heaving, particularly differential heaving that can be damaging to improvements. Linear improvements such as pipelines and canals are particularly susceptible to such impacts as they must meet stringent tolerances for line and grade. If not accounted for in project design, expansive soils could lead to degradation or even structural failure of facilities.

Highly expansive soils are found in the northern Delta, portions of Suisun Marsh, the western edge of the Delta, and the southern Delta near Tracy. In general, expansive soils are more likely to be present in well-developed soils in valley basins that have high clay contents, rather than in more organic rich soils or younger alluvial soils on floodplains. It is important that expansive soils be identified and mitigated during project design and construction, because structural problems resulting from construction on expansive soils may not become apparent for many years. Without mitigation, project impacts related to expansive soils could be significant.

It is unclear at this time how implementation of the Proposed Project would result in construction of projects, including the location, number, capacity, operational criteria, and methods and duration of construction activities. However, the Delta Plan discusses possible implementation of the projects included in the DWR Surface Water Investigation: North of Delta Offstream Storage Investigation, Los Vaqueros Reservoir Project, and the Upper San Joaquin River Basin Storage Investigation Plan.

In the EIS/EIR for the Los Vaqueros Reservoir Expansion Project (Reclamation et al. 2009), the lead agency found that project components could be located on expansive or corrosive soils; however, those components would not likely result in onsite or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse because proposed actions would require the preparation of a site-specific geotechnical investigation which would identify potential geologic hazards such as landslides, subsidence, and expansive/corrosive soils. Proposed improvements would be constructed according to industry standard practices and CCWD construction standards. Therefore, this impact was considered less than significant.

In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency found that compliance with standard design and construction practices, such as protection of steel with coatings, and use of corrosion resistant concrete, would ensure that impacts related to expansive or corrosive soil would be less than significant. No mitigation for this impact was needed.

The Delta Plan encourages other types of water supply projects, such as ocean desalination plants. The Delta Plan does not name any particular project, but representative desalination projects are contemplated in the city of Carlsbad and city of Huntington Beach. The Carlsbad Precise Development Plan and Desalination Plant Project EIR (City of Carlsbad 2005) evaluated operation of pumps (seawater intake pumps, filter effluent transfer pumps, and stand-alone pumps) for seawater desalination. The lead agency found that the impacts to geology and soils resulting from facility construction could be mitigated to less than significant levels by preparation of a pre-construction geotechnical investigation that includes a discussion of site-specific geology, soils, and foundational issues. Potential effects related to presence of expansive soils were identified the Draft Recirculated EIR for the Seawater Desalination Project at Huntington Beach (City of Huntington Beach 2010). The lead agency found that by conducting a site-specific geotechnical investigation to identify potential hazards, such as those associated with expansive soils, adhering to local construction requirements and industry standard practices, and incorporating measures in the Project design to minimize the shrink-swell hazards on project features, impacts on soils related to construction of the project were found to be less than significant.

Because of the uncertainties underlying this program-level assessment, impacts relating to the presence of expansive soils in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for named projects or projects encouraged by the Proposed Project to be located on expansive soils, this potential impact is considered **significant**.

11.5.3.1.6 Impact 11-6a: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

Operation of surface water storage facilities and canals could result in the occurrence of nuisance water (formation of surface springs and seeps) in adjacent areas due to leakage from such facilities. Nuisance water due to leakage could result in formation of areas of unstable soils and potentially result in on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse.

It is unclear at this time how implementation of the Proposed Project would result in operation of new reservoirs and canals or reoperation of existing reservoirs and canals, including the location, number, capacity, and operational criteria. However, the Delta Plan mentions possible implementation of the following surface storage projects: North of Delta Offstream Storage Investigation, Los Vaqueros Reservoir Project, and the Upper San Joaquin River Basin Storage Investigation Plan.

The EIS/EIR for the Los Vaqueros Reservoir Expansion Project (Reclamation et al. 2009) did not analyze the potential for impacts due to nuisance water. In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency did not analyze the potential for impacts due to nuisance water, but found that base flow in Calaveras Creek due to seepage under the dam is small (< 1 cubic foot per second) and would not change substantially with the Calaveras Dam Replacement Project EIR’s proposed project.

Because of the uncertainties underlying this program-level assessment, nuisance water impacts in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for operation of surface water storage facilities and canals constructed as a result of actions encouraged by the Proposed Project to result in nuisance water and potentially create an unstable soil unit, this potential impact is considered **significant** prior to mitigation.

11.5.3.1.7 Impact 11-7a: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

Construction of surface water projects, recycled wastewater and stormwater projects, and other reliable water supply projects could involve construction of dams, berms, and other embankments, which may result in an increased occurrence of landslides, typically shallow surficial failures on fill slopes. Landslides on fill embankments can occur especially during wet months, and also when seismic shaking events occur.

In the Los Vaqueros Reservoir Expansion EIS/EIR (Reclamation et al. 2009) the lead agency found that project facilities would be designed and engineered in accordance with seismic code requirements. As a result, the project would not expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking or seismic-related ground failure, including liquefaction and landslides. Therefore, this impact was considered less than significant. In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency found that impacts due to landslide activation as a result of construction activities would be less than significant with mitigation.

Ocean desalination plants might be constructed and operated outside the Delta to increase water supply. The construction of these facilities would have impacts similar to those described above for construction of water intakes, pumping plants, and associated conveyance facilities. In the Draft Recirculated EIR for the Seawater Desalination Project (City of Huntington Beach 2010), the City found that impacts due to geologic hazards could be mitigated to less than significant levels.

Because of the uncertainties underlying this program-level assessment, impacts relating to landslides in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for construction activities as a result of named projects or projects encouraged by the Proposed Project to result in an increased occurrence of landslides, this potential impact is considered **significant**.

11.5.3.1.8 Impact 11-8a: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

Construction-related activities for the types of projects identified in Section 11.5.3.1 could take place throughout the Delta, Delta watershed, and areas outside the Delta that use Delta water, as described in Section 2A, Proposed Project and Alternatives. Facilities may be sited in locations far from municipalities with sewer connections, and therefore could potentially require an on-site wastewater treatment system for the disposal of wastewater during project operation. If permanent facilities are constructed in remote locations, a septic tank or alternative wastewater disposal system would have to be installed for use during operation.

Soil properties that affect the ability to support the use of septic tanks or alternative waste disposal systems include:

- Saturated hydraulic conductivity
- Depth to a water table
- Potential for flooding and/or ponding
- Depth to bedrock or a cemented pan
- Subsoil texture

Based on the soil associations found within the Delta and Suisun Marsh, it is expected that the majority of the soils in this area will have some limitations for on-site wastewater disposal. The majority of the soils have a slow permeability, a shallow duripan or hardpan, or high potential for flooding or ponding, preventing the soil from properly treating effluent. Because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, impacts could be significant without appropriate project design and/or mitigation.

Upland regions of the Delta watershed and Delta water use area that have relative high hydraulic conductivity rates, no shallow water table, and no potential for flooding or ponding would likely be suitable for use of septic tanks or alternative waste water disposal systems if sewering is not an option. On the other hand, soils of basin floors within the San Joaquin Valley where artificial drainage is required and depth to groundwater is relatively shallow, may not be suitable for supporting septic systems.

It is unclear at this time how implementation of the Proposed Project would result in construction and operations of projects, including the location, number, size, methods, and duration of construction activities. Because of the uncertainties underlying this program-level assessment, impacts of soils incapable for supporting alternative wastewater systems in the Delta, Delta watershed, or areas outside the Delta that use Delta water cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, this potential impact is considered **significant**.

11.5.3.1.9 Impact 11-9a: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

Treatment plants, surface water and groundwater storage facilities, conveyance facilities (canals, pipelines, tunnels, siphons, and pumping plants), and groundwater wells could be constructed throughout the Project Area. If these facilities are constructed on soils with high levels of organic matter (such as peat or muck soils), structural problems could result over time because these soils do not provide stable bearing surfaces. High organic matter soils tend to settle and may decrease in volume as organic matter is oxidized. If not accounted for in project design, soils with high organic matter levels could degrade structural integrity of facilities.

In the Los Vaqueros Reservoir Expansion EIS/EIR (Reclamation et al. 2009), the lead agency did not specifically analyze impacts due to construction on peat or high organic matter soils but did find that project components could be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities; however, those components would not likely result in onsite or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse because proposed actions would require the preparation of a site-specific geotechnical investigation which would identify potential geologic hazards such as landslides, subsidence, and expansive/corrosive soils. Proposed improvements would be constructed according to industry standard practices and CCWD construction standards. Therefore, this impact was considered less than significant.

In the EIR for the Calaveras Dam Replacement Project (SFPUC 2011), the lead agency did not specifically identify impacts associated with high organic matter soils, but found that impacts related to soil or geologic unit instability would be significant. Mitigation measures included conducting a detailed geotechnical evaluation if fill placement creates final slopes greater than 20 feet high. The analysis would address static stability, hazards from fault offset, drainage, erosion control, and grading requirements. Ensuring that all measures specified for design and construction of the fills are implemented by the construction contractor would reduce this impact to less than significant after mitigation.

Ocean desalination plants might be constructed and operated outside the Delta to increase water supply. The construction of these facilities would have impacts similar to those described above for construction of water intakes, pumping plants, and associated conveyance facilities. In the Draft Recirculated EIR for the Seawater Desalination Project (City of Huntington Beach 2010), the City found that impacts due to geologic hazards could be mitigated to less than significant levels by conducting a site-specific geotechnical investigation to identify potential hazards, such as those associated with expansive soils, adhering to local construction requirements and industry standard practices, and incorporating measures in the project design to minimize the shrink-swell hazards on project features.

Because of the uncertainties underlying this program-level assessment, impacts due to construction activities on high organic matter soils in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on peat or other high organic matter soils (soil that is unstable, or that would become unstable as a result of the project), this potential impact is considered **significant**.

11.5.3.2 Delta Ecosystem Restoration

As described in Sections 2A and 2B, the Delta Plan does not direct the construction of specific projects, nor would projects be implemented under the direct authority of the Delta Stewardship Council. However, the Delta Plan seeks to improve the Delta ecosystem by encouraging various actions and projects, which if taken could lead to completion, construction and/or operation of projects that could improve the Delta ecosystem.

Features of such projects and actions that could be implemented as part of efforts to restore the Delta ecosystem include the following:

- Floodplain restoration
- Riparian restoration
- Tidal marsh restoration
- Stressor management
- Invasive species management (including removal of invasive vegetation)

The number and location of all potential projects that could be implemented are not known at this time. The following restoration areas, projects, and programs, however, are known to varying degrees and are named in the Delta Plan:

- Cosumnes River-Mokelumne River Confluence: North Delta Flood Control and Ecosystem Restoration Project
- Suisun Marsh Habitat Management, Preservation, and Restoration Plan (includes Hill Slough Restoration Project)
- Cache Slough Complex (includes Prospect Island Restoration Project)
- Yolo Bypass
- Lower San Joaquin River Bypass Proposal
- Water Quality Control Plan Update for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary (water flow objectives update)
- Delta Conservancy Strategic Plan
- Variance of the USACE’s Vegetation Policy
- California Department of Fish and Game’s (DFG) Stage Two Actions for Nonnative Invasive Species included in the Ecosystem Restoration Plan for the Sacramento-San Joaquin Bay Delta

The Proposed Project encourages the SWRCB to update the Water Quality Control Plan Update for the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary and develop, implement, and enforce updated flow requirements for the Delta and high-priority tributaries in the Delta watershed that are necessary to achieve coequal goals. As described in Section 2A, Proposed Project and Alternatives, these actions likely would result in a more natural flow regime in the Delta and Delta tributaries, and reduced export of water from the Delta. Water users in the areas outside the Delta that use Delta water would likely respond to reduced supplies by constructing facilities to improve water supply reliability and improve water quality. The geology- and soil-related impacts associated with these actions would be the same as those described above in Section 11.5.3.1 and Section 11.5.3.3.

There would be no geology impacts associated with obtaining a variance to the USACE Vegetation Policy because this policy concerns maintenance of existing levees and those that could be constructed in the future. Construction-related impacts are described in the following sections.

DFG's Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions (DFG 2011) Stage Two Actions for Nonnative Invasive Species (DFG 2011) identifies six actions for preventing the establishment of additional nonnative invasive species and reduce their economic and ecological impacts. These actions focus on monitoring, study, and coordination and encouragement of the continuation of these actions would not represent a physical change relative to existing conditions and would not have any geology- or soil-related impacts.

11.5.3.2.1 Impact 11-1b: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

Construction activities associated with ecosystem restoration actions encouraged by the Proposed Project (Section 11.5.3.2) include modification of landforms, breaching and modification of existing levees, construction of access roads, and utility relocation. Habitat restoration actions and locations will be project specific. Exposure of workers to risk of injury or death involving rupture of a known earthquake fault during construction would be low as these activities would be temporary or short-term. Any structures constructed could be exposed to risk of loss due to earthquake faults on a more permanent basis.

As described above in Section 11.5.3.1., there are two known earthquake faults with surface expression that cross the Project Area, the Concord fault and the Pittsburgh-Kirby Hills fault. Presence of these faults within the Alquist-Priolo Special Studies Zones, as delineated by the State Geologist, may impact construction activities. Structural setbacks may be required where active fault traces are present. Special design considerations may also be required in proximity to these faults to mitigate potential high ground acceleration. It should be noted that other active faults are present at depth within the Project area. These are known as blind thrust faults, and they have no surface expression. Potential impacts associated with these blind thrust faults do not include surface rupture, but are instead limited to strong ground motion, and are discussed in Section 11.5.3.2.2.

Documents reviewed for potential impacts in this project category included EIRs for the Suisun Marsh Management, Preservation, and Restoration Plan (Reclamation et al. 2010) and the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010) which are illustrative of some of the types of impacts associated with ecosystem restoration projects.

The Suisun Marsh Management, Preservation, and Restoration Plan EIS/EIR (Reclamation et al. 2010) evaluated three alternatives to restore marsh habitat and create managed wetlands in Suisun Marsh. In the EIR for this project, the lead agency found that although Suisun Marsh is traversed by active faults, the potential for damage to structures as a result of surface fault rupture, would be less than significant because project facilities would be small and occupied only a few hours (duck blinds) or located in limited locations in the Marsh (pump platforms) and placement of materials on levees would improve levee stability. No mitigation was required.

The North Delta Flood Control and Ecosystem Restoration Project involves more construction activities than the Suisun Marsh Management, Preservation, and Restoration Plan. In the draft and final EIRs for this project (DWR 2010), DWR found that impacts due to any increase in the potential for structural damage and injury caused by fault rupture would be less than significant because the risk of fault rupture is low due to the project's distance from active faults and that requirements for standard UBC Seismic Zone 3, California Building Standards Commission (CBSC), and county general plan construction standards would be incorporated into project design for applicable features to minimize the potential fault rupture hazards.

In addition to the encouragement of habitat restoration actions, the Proposed Project encourages the SWRCB to update the Water Quality Control Plan, including development of flow criteria for priority tributaries and new flow objectives for the Delta. Updating the plan would not require construction activities and would therefore have no geology-related impacts.

The location and unique characteristics of most of the specific projects encouraged by the Proposed Project are currently not known. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for restoration actions resulting from named projects or projects encouraged by the Proposed Project to be located on a known earthquake fault, this potential impact is considered **significant**.

11.5.3.2.2 Impact 11-2b: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

Impacts due to construction activities associated with ecosystem restoration would be similar to those described in Section 11.5.3.2.1. As described above, there are two known earthquake faults with surface expression that cross the project area, the Concord fault and the Pittsburgh-Kirby Hills fault. Presence of these faults within the Alquist-Priolo Special Studies Zones, as delineated by the State Geologist, may expose people or structures to adverse effects involving rupture of known earthquake faults. Exposure of workers to potentially adverse effects due to strong ground motion during construction would be low as these activities would be temporary or short-term. Any structures constructed could be exposed to risk of loss due to earthquake faults on a more permanent basis.

In the Suisun Marsh Management, Preservation, and Restoration Plan EIS/EIR (Reclamation et al. 2010), the lead agency found that the potential for damage to structures as a result ground shaking and/or seismically induced ground failure (liquefaction) would be less than significant because project facilities would be small and occupied only a few hours (duck blinds) or would be located in small, discrete locations in the Marsh (pump platforms) and placement of materials on levees would improve levee stability. No mitigation was required.

In the draft and final EIRs for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that impacts due to any increase in the potential for structural damage and injury caused by ground shaking from general construction, material hauling, and dredging would be less than significant because DWR has incorporated requirements for standard UBC Seismic Zone 3, CBSC, and county general plan construction standards into the project design for applicable features to minimize the potential for ground shaking hazards.

The location and unique characteristics of most of the specific projects encouraged by the Proposed Project are currently not known. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for restoration actions as a result of named projects or projects encouraged by the Proposed Project to be located in areas where strong ground motion during seismic events can and will occur, this potential impact is considered **significant**.

11.5.3.2.3 Impact 11-3b: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil That Is Unstable, or That Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction or Collapse

Construction activities associated with ecosystem restoration actions encouraged by the Proposed Project (Section 11.5.3.2) could include modification of landforms, breaching and modification of existing levees, construction of access roads, and utility relocation. Habitat restoration actions and locations will be project specific. Areas of unstable soils, with the potential for lateral spreading, subsidence, liquefaction, or collapse, could cause unsafe working conditions. Construction activities could occur in areas underlain by soft or loose soils, where high groundwater or seepage may be present and on sloping grounds. Exposure of workers to potential adverse effect due to lateral spreading, subsidence, liquefaction, or collapse during construction would be low as these activities would be temporary or short-term. Any structures constructed could be exposed to risk of loss due to earthquake faults on a more permanent basis.

Construction-related modifications of existing delta fluvial sediments, peats, and topsoils arising from grading required for development of various projects may result in a reduction of stability. Surcharging loads arising from placement of fill to locally raise grades may accelerate subsidence by causing consolidation of the peat and other unconsolidated sediments. Collapse of pore space in peat layers is the chief concern, but consolidation by compaction of saturated silts and sands is also a potential impact. Subsidence, particularly differential subsidence occurring after construction, can also result in distress to improvements.

Where existing surficial layers are removed by grading, potentially liquefiable sands may be exposed, which increased the risk of loss of bearing value, soil settlement, and lateral spreading during fault rupture-related seismic shaking events where transient higher pore-water pressures in groundwater cause the soil to liquefy. Repeated trips of loaded haul trucks on paved roads situated on top of shallow saturated sediments may also result in liquefaction and resultant deformational damage to roadbeds.

In addition to the encouragement of habitat restoration actions, the Proposed Project encourages the SWRCB to update the Water Quality Control Plan, including development of flow criteria for priority tributaries and new flow objectives for the Delta. Updating the plan would not require construction activities and would therefore have no geology-related impacts.

In the Suisun Marsh Management, Preservation, and Restoration Plan EIS/EIR (Reclamation et al. 2010), the lead agency did not specifically analyze potential impacts associated with location of the project on unstable geologic units or soils, but found that the potential for damage to structures as a result of ground shaking and/or seismically induced ground failure (liquefaction) would be less than significant and required no mitigation.

In the final EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that impacts due to any increase in the potential for structural damage and injury caused by development on materials subject to liquefaction could be significant. However, this impact could be mitigated to a less than significant level by preparation of a geotechnical report prior to the start of activities associated with levee construction, reinforcement, or modification; access road construction; or property enhancement. The project would be designed to accommodate the effects of liquefaction.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. Geotechnical investigations would be conducted during design at and near the locations of facilities to the depths necessary to characterize the subsurface conditions. The information would be used to determine foundation criteria that meet the settlement and bearing-capacity requirements for structures. However, because of the potential for ecosystem restoration actions as a result of named projects or projects encouraged by the Proposed Project to be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities, this potential impact is considered **significant**.

11.5.3.2.4 Impact 11-4b: Substantial Soil Erosion or the Loss of Topsoil

Construction of the types of ecosystem restoration projects listed in Section 11.5.3.2 would disturb large volumes of soil through excavating, earth moving, grading, filling, and stockpiling of soil material, and these disturbed soils could be susceptible to wind and water erosion. Without implementation of appropriate management measures, substantial soil erosion or loss of topsoil could occur.

In addition to the encouragement of habitat restoration actions that would require construction activities, the Proposed Project encourages the SWRCB to update the Water Quality Control Plan, including development of flow criteria for priority tributaries and new flow objectives for the Delta. Updating the plan would not require construction activities and would therefore have no geology- or soil-related impacts.

As described in Section 11.5.3.1.4, any construction project larger than 1 acre would be required to develop and implement an effective combination of erosion and sediment control BMPs to manage erosion and topsoil loss. Construction and post-construction BMPs would be identified in the project's SWPPP.

It is unclear at this time how implementation of the Proposed Project would result in specific construction activities, including the location, number, capacity, and methods and duration of construction activities. However, the Delta Plan encourages and/or mentions implementation of the nine projects listed in Section 11.5.3.2. Documents reviewed for potential impacts in this project category included EIRs for the Suisun Marsh Management, Preservation, and Restoration Plan (Reclamation et al. 2010) and the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010) which are illustrative of some of the types of impacts associated with ecosystem restoration projects.

Soils in the central Delta and portions of Suisun Marsh are particularly susceptible to erosion from wind and water (see Figures 11-8 and 11-9), and implementation of appropriate management practices would be especially important for projects constructed in these areas. In the Suisun Marsh Management, Preservation, and Restoration Plan EIS/EIR (Reclamation et al. 2010), the lead agency noted that even though soils were not highly erodible, ground disturbing activities, such as earthwork to breach levees and placement of fill to expand and maintain levees, could increase rates and extent of soil erosion. However, the lead agency also found that with implementation of a SWPPP and an erosion and sediment control plan as part of the project, potential impacts from accelerated soil erosion would be substantially avoided or minimized and less than significant. Restoration actions would restore natural processes interrupted by the existing levee and dike system, which would be beneficial.

In the final EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that potential impacts from accelerated runoff, erosion, and sedimentation as a result of grading, excavation, and levee construction activities would be less than significant because DWR would implement a SWPPP if the area of disturbance is more than 1 acre and would follow the appropriate County grading ordinance if the area of disturbance is less than 1 acre.

Because ecosystem restoration projects and actions encouraged by the Delta Plan would be required to comply with local requirements and State regulations, and would develop and implement a site-specific

SWPPP, soil erosion and topsoil loss would likely be minimized. The details of many of the aspects of these projects, however, are not currently known, and it is possible that significant soils loss could occur. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies of these potential projects. However, because of the potential for substantial soil erosion or loss of topsoil as a result of named projects or projects encouraged by the Proposed Project, this potential impact is considered **significant**.

11.5.3.2.5 Impact 11-5b: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

Expansive soils shrink and swell with wetting and drying cycles in the soil, creating an unstable foundation for rigid structures. Construction of the types of ecosystem restoration projects listed in Section 11.5.3.2 could expose or reduce the vertical distance to expansive clays in the subsurface. Expansive clays can cause heaving, particularly differential heaving that can be damaging to improvements. Impacts due to construction activities associated with ecosystem restoration would be similar to those described in Section 11.5.3.1.1. Exposure of workers to potential adverse effects of structures made unstable by expansive soils during construction would be low as these activities would be temporary or short-term. Any structures constructed could be exposed to risk of loss due to expansive soils on a more permanent basis.

Highly expansive soils are found in the northern Delta, portions of Suisun Marsh, the western edge of the Delta, and the southern Delta near Tracy. In general, expansive soils are more likely to be present in well-developed soils in valley basins that have high clay contents, rather than in more organic rich soils or younger alluvial soils on floodplains. In the Suisun Marsh Management, Preservation, and Restoration Plan EIS/EIR (Reclamation et al. 2010), the lead agency did not specifically analyze potential impacts associated with location of the project on expansive soils, but found that the potential for damage to structures as a result ground shaking and/or seismically induced ground failure (liquefaction) would be less than significant due to the limited exposed locations in the marsh (pump platforms) and because placement of materials on levees would improve levee stability. No mitigation was required.

In the final EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that potential impacts from any increase in the potential for structural damage and injury as a result of development on expansive soils would be significant, but could be mitigated to less than significant levels by conducting a geotechnical evaluation for expansive soils, and designing the project to accommodate effects of expansive soils.

The location and unique characteristics of most of the specific projects encouraged by the Proposed Project are currently not known. Because of the uncertainties underlying this program-level assessment, impacts relating to the presence of expansive soils in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for named projects or projects encouraged by the Proposed Project to be located on expansive or corrosive soils, this potential impact is considered **significant**.

11.5.3.2.6 Impact 11-6b: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

The implementation of ecosystem restoration projects such as floodplain or riparian restoration similar to the ones encouraged by the Delta Plan and listed above, have the potential to locally raise shallow groundwater levels. The greatest increases in groundwater levels would occur adjacent to floodplain restoration areas during high tide/high flow conditions, with effects decreasing with distance from the restoration areas. Shallow groundwater levels could result in water-logging (anoxia) of crop root zones, reducing productivity and potentially necessitating a greater degree of agricultural drainage pumping.

An example of such impacts that could result from an ecosystem restoration project is provided in the EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010). The lead agency found that potential significant impacts could result from groundwater seepage onto adjacent lands. However, these impacts would be reduced to less than significant after mitigation measures to control seepage are implemented. Such mitigation measures would involve the creation of a seepage monitoring program to verify that seepage rates will not increase significantly, and to help implement an active seepage management program. Common methods of seepage control would be implemented, such as internal drainage, seepage berms, cutoff walls, passive relief wells, and active pumping wells.

Operation of permanent wetlands or ponds created during ecosystem restoration actions resulting from named projects or projects encouraged by the Proposed Project could also result in the occurrence of nuisance water (formation of surface springs and seeps) in adjacent areas due to leakage of such facilities. Nuisance water due to leakage could result in formation of areas of unstable soils and potentially result in on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse.

In the final EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that restoration actions had the potential to increase groundwater seepage to adjacent lands. Impacts of this seepage were considered significant but could be mitigated to less than significant levels by controlling seepage through use of internal drainage, seepage berms, cutoff walls, and active pumping wells.

Because of the uncertainties underlying this program-level assessment, nuisance water impacts in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for ecosystem restoration actions as a result of named projects or projects encouraged by the Proposed Project to result in high groundwater, nuisance water, or related potentially unstable soil, this potential impact is considered **significant**.

11.5.3.2.7 Impact 11-7b: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

Delta ecosystem restoration projects may involve levee modification (construction, removal, or degradation), Levee modification during ecosystem restoration actions as a result of named projects or projects encouraged by the Proposed Project (Section 11.5.3.2) may result in an increased occurrence of landslides, typically shallow surficial failures on fill slopes. Landslides on fill embankments can occur especially during wet months, and also when seismic shaking events occur.

In the Suisun Marsh Management, Preservation, and Restoration Plan EIS/EIR (Reclamation et al. 2010), the lead agency found that the potential impacts associated with creation of unstable cut and fill slopes would be less than significant because excavation would be limited to interior areas of managed wetlands and center channels of tidal sloughs. Fill would be applied mainly to improve interior and exterior levees. Riprap and other bank protection measures would be implemented to protect newly created or modified slopes from excessive instability and erosion. The potential for damage to structures as a result of landslides would be less than significant because few structures would be constructed in areas subject to damage from landslides, and because few of these structures would be occupied.

Because of the uncertainties underlying this program-level assessment, impacts relating to landslides in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for construction activities associated with restoration actions resulting from named projects or projects encouraged by the Proposed Project to result in an increased occurrence of landslides, this potential impact is considered **significant**.

11.5.3.2.8 Impact 11-8b: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

The types of projects identified in Section 11.5.3.2 could take place throughout the Delta, Delta watershed, and areas outside the Delta that use Delta water, as described in Section 2A, Proposed Project and Alternatives. These facilities may be sited in locations far from municipalities with sewer connections, and therefore could potentially require an on-site wastewater treatment system for the disposal of wastewater during project operation. If permanent facilities are constructed in remote locations, a septic tank or alternative wastewater disposal system would have to be installed for use during operation.

Based on the soil associations found within the Delta and Suisun Marsh, it is expected that the majority of the soils in this area will have some limitations for on-site wastewater disposal. The majority of the soils have a slow permeability, a shallow duripan or hardpan, or high potential for flooding or ponding, preventing the soil from properly treating effluent. Because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, impacts could be significant without appropriate project design and/or mitigation.

It is unclear at this time how implementation of the Proposed Project would result in construction and operations of projects, including the location, number, size, methods, and duration of construction activities. Because of the uncertainties underlying this program-level assessment, impacts of soils incapable for supporting alternative wastewater systems in the Delta, Delta watershed, or areas outside the Delta that use Delta water cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, this potential impact is considered **significant**.

11.5.3.2.9 Impact 11-9b: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

Ecosystem restoration activities as a result of named projects or projects encouraged by the Proposed Project (Section 11.5.3.2) could be constructed on soils with high levels of organic matter (such as peat or muck soils). Structural problems could result over time because these soils do not provide stable bearing surfaces. High organic matter soils tend to settle and may decrease in volume as organic matter is oxidized. Delta ecosystem restoration projects may involve levee modification (construction, removal, or degradation), Levee modification during ecosystem restoration actions as a result of named projects or projects encouraged by the Proposed Project (Section 11.5.3.2) may result in placement of materials in areas of high organic matter (peat) soils.

Construction-related modifications of existing delta fluvial sediments and peat soils arising from grading required for development of various ecosystem restoration projects may result in a reduction of stability. Surcharging loads arising from placement of fill to locally raise grades may accelerate subsidence by causing consolidation of the peat and other unconsolidated sediments. Collapse of pore space in peat layers is the chief concern, but consolidation by compaction of saturated silts and sands is also a potential impact. The operation of pumping facilities, weirs/gates, pipelines, and siphons in areas of unstable high organic matter soils could be disrupted for several reasons including roadway collapse, differential subsidence and compaction, pipe breaking or collapse.

In the final EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that placement of material (from levee degradation, breaching, or dredging) or imported soil for levee reinforcement, modification, or construction in area with peat soils could result in consolidation of these soils and land subsidence. Potential impacts associated with any increase in the potential for land subsidence were considered less than significant because project design and construction measures would consider the potential for land subsidence and appropriate levee standards and design criteria would be incorporated, reviewed and approved by the Federal Emergency Management Agency (FEMA).

Because of the uncertainties underlying this program-level assessment, impacts due to construction activities on high organic matter soils in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for ecosystem restoration actions resulting from named projects or projects encouraged by the Proposed Project to be located on located on peat or other high organic matter soils (soil that is unstable, or that would become unstable as a result of the project), this potential impact is considered **significant**.

11.5.3.3 Water Quality Improvement

As described in Sections 2A and 2B, the Delta Plan does not direct the construction of specific projects, nor would projects be implemented under the direct authority of the Delta Stewardship Council. However, the Delta Plan seeks to improve water quality by encouraging various actions and projects, which if taken could lead to completion, construction and/or operation of projects that could improve water quality.

Actions would include implementation of plans/programs that lead to reduced constituents from agricultural runoff and wastewater treatment plants.

Associated projects could include construction and operation and maintenance of:

- Water treatment plants
- Conveyance facilities (pipelines and pumping plants)
- Wastewater treatment and recycle facilities
- Municipal stormwater treatment facilities
- Agricultural runoff treatment (eliminate, capture and treat/reuse)
- Wellhead treatment facilities
- Wells (withdrawal, recharge, and monitoring)

The number and location of all potential actions and projects that could be implemented is currently not known. Various projects, however, are known to some degree and are named in the Delta Plan. These are:

- Central Valley Drinking Water Policy
- Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS)
- Water Quality Control Plan Update for the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary (water flow objectives update)
- SWRCB/Central Valley RWQCB Strategic Workplan
- Complete the following regulatory processes, research, and monitoring:
  - Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for diazinon and chlorpyrifos
  - Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for pyrethroids
  - Total Maximum Daily Load and Basin Plan Amendments for selenium and methylmercury
- North Bay Aqueduct Alternative Intake Project

11.5.3.3.1 Impact 11-1c: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

Actions encouraged by the Proposed Project to improve water quality (Section 11.5.3.3), including projects that could result from the completion of the Central Valley Drinking Water Policy and the SWRCB/Central Valley RWQCB Strategic Workplan, could include water treatment plants, wastewater treatment plants, conveyance facilities, well installation, and wellhead treatment. CV-SALTS could result in the construction of new wastewater treatment facilities. These facilities could be constructed throughout the Study Area. Similarly, the recommendations for the SWRCB and RWQCBs to develop and adopt objectives for nutrients in the Delta and Delta watershed and complete the processes underway for Total Maximum Daily Load development also could result in the construction and operation of these types of facilities. The potential construction-related impacts related to earthquake faults would be similar to those described in Section 11.5.3.1 above for facilities to improve water supply reliability.

As described above in Section 11.5.3.1.1, there are two known earthquake faults with surface expression that cross the Delta. Presence of these faults may impact construction activities. Structural setbacks may be required where active fault traces are present. Special design considerations may also be required in proximity to these faults to mitigate potential high ground acceleration. It should be noted that other active faults are present at depth within the Project area. These are known as blind thrust faults, and they have no surface expression. Potential impacts associated with these blind thrust faults do not include surface rupture, but are instead limited to strong ground motion, and are discussed in Section 11.5.3.3.2.

The Delta Plan encourages implementation of the North Bay Aqueduct Alternative Intake Project. The new North Bay Alternative Intake structure would be located on the Sacramento River in a rural area of Sacramento or Yolo County and the new pipeline would extend from the new intake structure to the existing North Bay Regional Water Treatment Plant. This diversion/intake structure and water conveyance pipeline are similar to those associated with the Davis-Woodland Water Supply Project, which, while not named in the Delta Plan, provides analogous information. The Davis-Woodland Water Supply Project EIR (City of Davis et al. 2007) found that the project could expose people or structures to substantial adverse effects, including the risk of loss, injury, or death involving rupture of a known earthquake fault and that the impact would be significant. Specific mitigation measures were identified to reduce the level of impact to less than significant after mitigation.

Actions encouraged by the Proposed Project to improve water quality also could include facilities for the capture and treatment/reuse of agricultural runoff. These types of actions could have geology-related impacts if the footprint of those facilities lies on or near a known earthquake fault. The EIR for the Grasslands Bypass Project (Reclamation and San Luis & Delta-Mendota Water Authority 2008) illustrates some of the types of potential impacts associated with actions to improve the quality of agricultural drainage water. The EIR did not analyze geologic or seismic impacts as a result of the project.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on a known earthquake fault, this potential impact is considered **significant**.

11.5.3.3.2 Impact 11-2c: Construction and Operations of Projects Could Be Subjected to Strong Ground Motion Associated with Seismic Shaking

The potential impacts relative to strong ground motion and seismic shaking would be similar to those described in Section 11.5.3.1.2 for facilities to improve water supply reliability. Due to the presence of nearby faults, including: a) known active faults within the Project Area that have surface expression; b) known active faults within the Project Area that do not have surface expression (such as the Midland

and Vernalis blind thrust faults); and c) known regional active faults in the vicinity of the project area that have or do not have surface expression, strong ground motion during seismic events can and will occur within the Project Area in the future. The effects of strong ground motion (shaking) are many, among which the most significant are direct structural deformation and failure of inhabited structures and ground failure beneath inhabited structures. Other, less significant effects can include damage to uninhabited structures, pipelines, canals, power lines, and other constructed improvements.

Completed CEQA documents for projects with characteristics similar to those listed above for water quality improvement provide perspective on the types of geology-related impacts that might result. For example, the EIRs for the Grasslands Bypass (Reclamation and San Luis & Delta-Mendota Water Authority 2008) and the Davis-Woodland Water Supply Project (City of Davis et al. 2007) are illustrative of some of the types of impacts associated with water quality improvement. The Davis-Woodland project could expose people or structures to substantial adverse effects, including the risk of loss, injury, or death involving rupture of a known earthquake fault, strong seismic shaking, seismic-related ground failure, including liquefaction, and landslides and the City found that the impact would be significant. Specific mitigation measures were identified to reduce the level of impact to less than significant after mitigation. No geologic or seismic impacts were analyzed for the Grasslands Bypass project.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located in areas where strong ground motion during seismic events can and will occur, this potential impact is considered **significant**.

11.5.3.3.3 Impact 11-3c: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil That Is Unstable, or That Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction or Collapse

Construction-related activities for projects associated with water quality improvement (Section 11.5.3.3) could require the use of heavy equipment, such as excavators, graders, scrapers, bulldozers, backhoes, and concrete mixing and pumping trucks, along with haul trucks that would be used to move borrow and/or spoils and other materials. The potential construction-related geology impacts would be similar to those described in Section 11.5.3.1.3 for facilities to improve water supply reliability.

Operation of the types of facilities identified in Section 11.5.3.3 in areas of unstable soils, and with the potential for lateral spreading, subsidence, liquefaction or collapse, could be disrupted for several reasons including roadway collapse, differential subsidence and compaction, pipe breaking or collapse.

The Davis-Woodland Water Supply Project EIR (City of Davis et al. 2007) evaluated whether the project could be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, potentially resulting in on- or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse. The City found that impacts associated with unstable, or potentially unstable geologic units and soils would be less than significant because these soils are located in areas with flat topography and are not in the vicinity of active earthquake faults such that landslides, lateral spreading, liquefaction, or collapse would not be likely to occur. No geologic or seismic impacts were analyzed for the Grassland Bypass Project (Reclamation and San Luis & Delta-Mendota Water Authority 2008).

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. Geotechnical investigations would be conducted during design at and near the locations of facilities to the depths necessary to characterize the subsurface conditions. The information would be used to determine foundation criteria that meet the settlement and bearing-capacity requirements for structures. However, because of the potential for facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities, this potential impact is considered **significant**.

11.5.3.3.4 Impact 11-4c: Substantial Soil Erosion or the Loss of Topsoil

Construction of the types of water quality improvement projects listed in Section 11.5.3.3 could disturb large volumes of soil through excavating, earth moving, grading, filling, and stockpiling of soil material, and these disturbed soils could be susceptible to wind and water erosion. Without implementation of appropriate management measures, substantial soil erosion or loss of topsoil could occur. The construction of new wells has the potential to increase soil erosion at each individual well installation site.

As described in Section 11.5.3.1.4, any construction project more than 1 acre in size would be required develop and implement an effective combination of erosion and sediment control BMPs to manage erosion and topsoil loss. Construction and post-construction BMPs would be identified in the project's SWPPP.

The Delta Plan encourages implementation of the North Bay Aqueduct Alternative Intake Project. The EIR for an analogous project, the Davis-Woodland Water Supply Project (City of Davis et al. 2007), evaluated whether the project could result in substantial soil erosion or the loss of topsoil. The City found that impacts associated with soil erosion and loss of topsoil would be significant but could be mitigated to less than significant levels through preparation and implementation of an SWPPP and various BMPs. Erosion control plans would be prepared for installation and construction of new groundwater wells. No soil erosion impacts were analyzed for the Grassland Bypass Project (Reclamation and San Luis & Delta-Mendota Water Authority 2008).

Because water quality improvement projects and actions encouraged by the Delta Plan would be required to comply with local requirements and State regulations, and would develop and implement a site-specific SWPPP, soil erosion and topsoil loss would likely be minimized. The details of many of the aspects of these projects, however, are not currently known, and it is possible that significant soils loss could occur. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies of these potential projects. However, because of the potential for substantial soil loss or loss of topsoil associated with construction and operation of facilities constructed as a result of named projects or projects encouraged by the Proposed Project, this potential impact is considered **significant**.

11.5.3.3.5 Impact 11-5c: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

Grading activities for the types of projects identified in Section 11.5.3.3 could expose or reduce the vertical distance to expansive clays in the subsurface. The potential construction-related geology impacts would be similar to those described in Section 11.5.3.1.5 for facilities to improve water supply reliability. Expansive clays can cause heaving, particularly differential heaving that can be damaging to improvements. Linear improvements such as pipelines and canals are particularly susceptible to such impacts as they must meet stringent tolerances for line and grade.

The Delta Plan encourages implementation of the North Bay Aqueduct Alternative Intake Project. The EIR for an analogous project, the Davis-Woodland Water Supply Project (City of Davis et al. 2007), evaluated whether the project could be located on expansive soil, creating substantial risks to life or property. The City found that impacts associated with expansive soils would be less than significant because geotechnical investigations would be conducted and recommendations incorporated into the Project design. Therefore, the Project would be constructed to industry standards to protect against impacts from expansive soils. No mitigation would be required. Another document reviewed for potential impacts of an analogous project is the Grassland Bypass Project EIS/EIR (Reclamation and San Luis &

Delta-Mendota Water Authority 2008). No geologic or seismic impacts were analyzed for the Grassland Bypass project.

Because of the uncertainties underlying this program-level assessment, impacts relating to the presence of expansive soils in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on expansive soils, this potential impact is considered **significant**.

11.5.3.3.6 Impact 11-6c: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

Operation of treatment facilities and pipelines could result in the occurrence of nuisance water (formation of surface springs and seeps) in adjacent areas due to leakage from such facilities. Nuisance water due to leakage could result in formation of areas of unstable soils and potentially result in on- or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse.

The Delta Plan encourages implementation of the North Bay Aqueduct Alternative Intake Project. The EIR for an analogous project, the Davis-Woodland Water Supply Project (City of Davis et al. 2007) did not analyze the potential for impacts due to nuisance water.

Because of the uncertainties underlying this program-level assessment, nuisance water impacts in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for operation of treatment facilities and pipelines constructed as a result of named projects or projects encouraged by the Proposed Project to result in nuisance water and potentially create an unstable soil unit, this potential impact is considered **significant**.

11.5.3.3.7 Impact 11-7c: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

Construction of water or wastewater treatment facilities, municipal stormwater facilities, or agricultural runoff treatment facilities would involve construction or modification of embankments and may result in an increased occurrence of landslides, typically shallow surficial failures on fill slopes. Landslides on fill embankments can occur especially during wet months, and also when seismic shaking events occur. The potential construction-related geology impacts would be similar to those described in Section 11.5.3.1.7 above for facilities to improve water supply reliability.

In the Davis-Woodland Water Supply Project EIR (City of Davis et al. 2007), the City found that the project could expose people or structures to substantial adverse effects, including the risk of loss, injury, or death involving landslides and that the impact would be significant. Mitigation measures including conduct of a detailed geotechnical study of the project area that includes the liquefaction potential, bearing strength of soils and levee slope stability and incorporating the findings of the study into facility design would reduce this impact to less than significant after mitigation. No geologic or seismic impacts were analyzed in the Grassland Bypass Project EIS/EIR (Reclamation and San Luis & Delta-Mendota Water Authority 2008).

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for construction activities associated with named projects or projects encouraged by the Proposed Project to result in an increased occurrence of landslides, this potential impact is considered **significant**.

11.5.3.3.8 Impact 11-8c: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

Construction-related activities for the types of projects identified in Section 11.5.3.3 could be take place throughout the Delta, Delta watershed, and areas outside the Delta that use Delta water, as described in Section 2A, Proposed Project and Alternatives. These facilities may be sited in locations far from municipalities with sewer connections, and therefore could potentially require an on-site wastewater treatment system for the disposal of wastewater during project operation. If permanent facilities are constructed in remote locations, a septic tank or alternative wastewater disposal system would have to be installed for use during operation.

Based on the soil associations found within the Delta and Suisun Marsh, it is expected that the majority of the soils in this area will have some limitations for on-site wastewater disposal. The majority of the soils have a slow permeability, a shallow duripan or hardpan, or high potential for flooding or ponding, preventing the soil from properly treating effluent. Because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, impacts could be significant without appropriate project design and/or mitigation.

Upland regions of the Delta watershed and Delta water use area that have relatively high hydraulic conductivity rates, no shallow water table, and no potential for flooding or ponding would likely be suitable for use of septic tanks or alternative waste water disposal systems if sewering is not an option. On the other hand, soils of basin floors within the San Joaquin Valley where artificial drainage is required and depth to groundwater is relatively shallow, may not be suitable for supporting septic systems.

It is unclear at this time how implementation of the Proposed Project would result in construction and operations of projects, including the location, number, size, methods, and duration of construction activities. Because of the uncertainties underlying this program-level assessment, impacts of soils incapable for supporting alternative wastewater systems in the Delta, Delta watershed, or areas outside the Delta that use Delta water cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, this potential impact is considered **significant**.

11.5.3.3.9 Impact 11-9c: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

Construction-related grading activities for the types of projects identified in Section 11.5.3.3 could be constructed throughout the Project Area. If these facilities are constructed on soils with high levels of organic matter (such as peat or muck soils), structural problems could result over time because these soils do not provide stable bearing surfaces. High organic matter soils tend to settle and may decrease in volume as organic matter is oxidized. If not accounted for in project design, soils with high organic matter levels could degrade structural integrity of facilities.

The Davis-Woodland Water Supply Project EIR (City of Davis et al. 2007) did not evaluate whether the project could be located on peat or other high organic matter soils, but did evaluate whether the project could be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, potentially resulting in on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse. The City found that impacts associated with unstable, or potentially unstable geologic units and soils would be less than significant because these soils are located in areas with flat topography and are not in the vicinity of active earthquake faults such that landslides, lateral spreading, liquefaction, or collapse would not be likely to occur.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on high organic matter soils (soil that is unstable, or that would become unstable as a result of the project), this potential impact is considered **significant**.

11.5.3.4 Flood Risk Reduction

As described in Sections 2A and 2B, the Delta Plan does not direct the construction of specific projects, nor would projects be implemented under the direct authority of the Delta Stewardship Council. However, the Delta Plan seeks to reduce the risk of floods in the Delta by encouraging various actions, which if taken could lead to completion, construction and/or operation of projects that could reduce flood risks in the Delta. Such projects and their features could include the following:

- Setback levees
- Floodplain expansion
- Levee maintenance
- Levee modification
- Dredging
- Stockpiling of rock for flood emergencies
- Subsidence reversal
- Reservoir reoperation

The number and location of all potential projects that would be implemented is not known at this time. One possible project, however, is known to some degree and is named in the Delta Plan, specifically the Sacramento Deep Water Ship Channel and Stockton Deep Water Ship Channel Dredging (the United States Army Corps of Engineer's *Delta Dredged Sediment Long-Term Management Strategy* included in Appendix C, Attachment C-7 of this EIR). The Proposed Project also names DWR's *A Framework for Department of Water Resources Investments in Delta Integrated Flood Management*, which could, upon completion, provide guidance on the prioritization flood protection investments.

11.5.3.4.1 Impact 11-1d: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

Construction of facilities associated with flood risk reduction including setback levees, levee modification, and dredging could result in exposure of people or structures to adverse effects involving the rupture of known earthquake faults. These facilities could be constructed in the Delta or Delta watershed, as described in Section 2A, Proposed Project and Alternatives. Once constructed, operation of these facilities would continue to expose people and structures to earthquake hazards. Exposure of workers to risk of injury or death involving rupture of a known earthquake fault during construction would be low as these activities would be temporary or short-term. Any structures constructed, including levees, could be exposed to risk of loss due to earthquake faults on a more permanent basis.

As described in Section 11.5.3.2.1 (ecosystem restoration), these types of impacts were evaluated in the EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), a named project that provides an assessment of impacts that are analogous to the levee construction activities encouraged by the Delta Plan. In the EIR for this project, DWR found that impacts due to any increase in the potential for structural damage and injury caused by fault rupture would be less than significant because the risk of fault rupture is low due to the project's distance from active faults and that requirements for standard UBC Seismic Zone 3, CBSC, and county general plan construction standards would be incorporated into project design for applicable features to minimize the potential fault rupture hazards.

The Proposed Project also would encourage the development of sites to stockpile rock for use in flood emergencies. These activities could be located on or near existing earthquake faults. The Initial Study and Proposed Mitigated Negative Declaration (IS/MND) for DWR's Delta Emergency Rock and Transfer Facilities Project (DWR 2007c) provided analogous information on the types of impacts that could result from these kinds of activities. In the IS/MND for the project, DWR evaluated the environmental effects of stockpiling rock and setting up barge loading facilities at strategic locations around the Delta for use during emergency flood fighting operations in the event of a catastrophic flooding event in the Delta. Based on the evaluation in the IS/MND, DWR concluded that the Delta Emergency Rock and Transfer Facilities Project proposed project would have less than significant impacts related to rupture of a known earthquake fault because the nature of the project (stockpiling rock on previously disturbed flat graded lots) would not pose a substantial risk or threat of injury in the event of fault rupture.

Activities to reduce flood risk or increase channel depths could include dredging in and near the Delta. These activities could occur as part of maintenance of the Sacramento Deep Water Ship Channel and Stockton Deep Water Ship Channel Dredging as described in Section 2A, Proposed Project and Alternatives, for the Delta Dredged Sediment Long-Term Management Strategy. The Draft Supplemental EIS/Subsequent EIR for the Sacramento River Deep Water Ship Channel (USACE and Port of West Sacramento 2011), a project that is both encouraged by the Proposed Project and serves as an example of dredging projects, analyzed proposed dredging activities, but did not analyze any seismic impacts related to known earthquake faults.

As described in Section 11.5.3.1.1, there are two known earthquake faults with surface expression that cross the Project Area. Presence of these faults may impact construction activities. Special design considerations may be required in proximity to these faults to mitigate potential high ground acceleration. It should be noted that other active faults are present at depth within the Project area. These are known as blind thrust faults, and they have no surface expression. Potential impacts associated with these blind thrust faults do not include surface rupture, but are instead limited to strong ground motion, and are discussed in Section 11.5.3.4.2.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for levees and other facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on a known earthquake fault, this potential impact is considered **significant**.

11.5.3.4.2 Impact 11-2d: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

The potential construction-related geology impacts would be similar to those described in Section 11.5.3.1.2 for facilities to improve water supply reliability. Due to the presence of nearby faults, including: a) known active faults within the Project Area that have surface expression; b) known active faults within the Project Area that do not have surface expression (such as the Midland and Vernalis blind thrust faults); and c) known regional active faults in the vicinity of the project area that have or do not have surface expression, strong ground motion during seismic events can and will occur within the Project Area in the future. The effects of strong ground motion (shaking) are many, among which the most significant are direct structural deformation and failure of inhabited structures, ground failure beneath inhabited structures, or ground failure beneath critical infrastructure such as dams (including levees). Other, less significant effects can include damage to uninhabited structures, pipelines, canals, power lines, aboveground and underground storage tanks, and other constructed improvements.

Construction of facilities associated with flood risk reduction including setback levees, levee modification, and dredging could result in exposure of people or structures to adverse effects due to strong ground motion associated with seismic shaking. These facilities could be constructed in the Delta and Delta watershed, as described in Section 2A, Proposed Project and Alternatives. Exposure of workers to risk of injury or death due to seismic shaking during construction would be low as these activities would be temporary or short-term. Any structures, including levees, constructed could be exposed to risk of loss due to strong ground motion associated with seismic shaking on a more permanent basis.

The North Delta Flood Control and Ecosystem Restoration Project was discussed for Impact 11-1d (Section 11.5.3.4.1). In the EIR for this project (DWR 2010), DWR found that impacts due to any increase in the potential for structural damage and injury caused by ground shaking would be less than significant because requirements for standard UBC Seismic Zone 3, CBSC, and county general plan construction standards would be incorporated into project design for applicable features to minimize the potential ground shaking hazards.

In the IS/MND for the Delta Emergency Rock and Transfer Facilities Project (DWR 2007c), DWR concluded that the Proposed Project would have less than significant impacts related to strong seismic ground shaking because the nature of the project (stockpiling rock on previously disturbed flat graded lots) would not pose a substantial risk or threat of injury in the event of strong seismic ground shaking.

Activities to reduce flood risk or increase channel depths could include dredging in and near the Delta. These activities could occur as part of maintenance of the Sacramento Deep Water Ship Channel and Stockton Deep Water Ship Channel Dredging as described in Section 2A, Proposed Project and Alternatives, for the Delta Dredged Sediment Long-Term Management Strategy. The Draft Supplemental EIS/Subsequent EIR for the Sacramento River Deep Water Ship Channel (USACE and Port of West Sacramento 2011), a project that is both encouraged by the Proposed Project and serves as an example of dredging projects, analyzed proposed dredging activities, but did not analyze any seismic impacts related to strong ground motion.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for levees and other facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located in areas where strong ground motion during seismic events can and will occur, this potential impact is considered **significant**.

11.5.3.4.3 Impact 11-3d: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil That Is Unstable, or That Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction or Collapse

Construction of facilities associated with flood risk reduction (Section 11.5.3.4) could require the use of heavy equipment, such as excavators, graders, scrapers, bulldozers, and backhoes, along with haul trucks that would be used to move borrow and/or spoils and other materials. Areas of unstable soils, with the potential for lateral spreading, subsidence, liquefaction, or collapse, could cause unsafe working conditions. Construction activities could occur in areas underlain by soft or loose soils, where high groundwater or seepage may be present and on sloping grounds. The potential construction-related geology impacts would be similar to those described in Section 11.5.3.1.3 for facilities to improve water supply reliability. Once in operation, the types of features identified in Section 11.5.3.4 could be exposed to impacts related to unstable soils and soils with the potential for lateral spreading, subsidence, liquefaction or collapse, including roadway collapse, differential subsidence and compaction, or collapse.

The North Delta Flood Control and Ecosystem Restoration Project was discussed for Impact 11-1d (Section 11.5.3.4.1). In the EIR for this project, DWR found that impacts due to any increase in the potential for structural damage and injury caused by development on materials subject to liquefaction would be less than significant.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. Geotechnical investigations would be conducted during design at and near the locations of facilities to the depths necessary to characterize the subsurface conditions. The information would be used to determine foundation criteria that meet the settlement and bearing-capacity requirements for structures. However, because of the potential for levees and other facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities, this potential impact is considered **significant**.

11.5.3.4.4 Impact 11-4d: Substantial Soil Erosion or the Loss of Topsoil

Construction of facilities associated with flood risk reduction (Section 11.5.3.4) would disturb large volumes of soil through excavating, earth moving, grading, filling, and stockpiling of soil material, and these disturbed soils could be susceptible to wind and water erosion. Without implementation of appropriate management measures, substantial soil erosion or loss of topsoil could occur. Soils in the central Delta and portions of Suisun Marsh are particularly susceptible to erosion from wind and water (see Figures 11-8 and 11-9), and implementation of appropriate management practices would be especially important for projects constructed in these areas.

As described above in Section 11.5.3.1.4, any construction project more than 1 acre in size would be required develop and implement an effective combination of erosion and sediment control BMPs to manage erosion and topsoil loss. Construction and post-construction BMPs would be identified in the project's SWPPP.

The North Delta Flood Control and Ecosystem Restoration Project was discussed in the ecosystem restoration subsection (Section 11.5.3.2.4). In the EIR for this project, DWR found that potential impacts from accelerated runoff, erosion, and sedimentation as a result of grading, excavation, and levee construction activities would be less than significant because DWR would implement an SWPPP if the area of disturbance is more than 1 acre and follow the appropriate county grading ordinance if the area of disturbance is less than 1 acre.

In the IS/MND for the Delta Emergency Rock and Transfer Facilities Project (DWR 2007c), DWR concluded that the Delta Emergency Rock and Transfer Facilities Project IS/MND proposed project would have less than significant impacts related to soil erosion and loss of topsoil because DWR would implement BMPs for all construction activities in accordance with applicable federal and State regulations. Contractors would be required to implement these measures to control soil erosion and waste discharges.

In addition to levee construction and levee repairs the Delta Plan encourages implementation of dredging to reduce flood risk including hydraulic dredging in the Sacramento Deep Water Ship Channel and Stockton Deep Water Ship Channel Dredging. The Draft Supplemental EIS/Subsequent EIR for the Sacramento River Deep Water Ship Channel (USACE and Port of West Sacramento 2011), a project that is both encouraged by the Proposed Project and serves as an example of dredging projects, analyzed proposed dredging activities, but did not analyze any impacts related to soil erosion or loss of topsoil.

Because ecosystem restoration projects and actions encouraged by the Delta Plan would be required to comply with local requirements and State regulations, and would develop and implement a site-specific SWPPP, soil erosion and topsoil loss would likely be minimized. The details of many of the aspects of these projects, however, are not currently known, and it is possible that significant soils loss could occur. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for substantial soil erosion or loss of topsoil resulting from named projects or projects encouraged by the Proposed Project, this potential impact is considered **significant**.

11.5.3.4.5 Impact 11-5d: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

Expansive soils shrink and swell with wetting and drying cycles in the soil, creating an unstable foundation for rigid structures. Construction of facilities associated with flood risk reduction (Section 11.5.3.4) could expose or reduce the vertical distance to expansive clays in the subsurface. Expansive clays can cause heaving, particularly differential heaving that can be damaging to improvements. Linear improvements such as levees are particularly susceptible to such impacts as they must meet stringent tolerances for line and grade. If not accounted for in project design, expansive soils could lead to degradation or even structural failure of facilities.

In the EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that potential impacts from any increase in the potential for structural damage and injury as a result of development on expansive soils would be significant, but could be mitigated to less than significant levels by conducting a geotechnical evaluation for expansive soils, and designing the project to accommodate effects of expansive soils.

Because of the uncertainties underlying this program-level assessment, impacts relating to the presence of expansive soils in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for levees and other facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on expansive soils, this potential impact is considered **significant**.

11.5.3.4.6 Impact 11-6d: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

Construction of facilities associated with flood risk reduction (Section 11.5.3.4), particularly construction of setback levees and floodplain expansion could result in the occurrence of nuisance water (formation of surface springs and seeps) in adjacent areas due to leakage during operation. Nuisance water due to leakage could result in formation of areas of unstable soils and potentially result in on- or off-site landslides, lateral spreading, subsidence, liquefaction, or collapse.

In the EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that restoration actions had the potential to increase groundwater seepage to adjacent lands. Impacts of this seepage were considered significant but could be mitigated to less than significant levels by controlling seepage through use of internal drainage, seepage berms, cutoff walls, and active pumping wells.

Because of the uncertainties underlying this program-level assessment, nuisance water impacts in the Project Area cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for levee construction and floodplain expansion associated with named projects or projects encouraged by the Proposed Project to result in nuisance water and potentially create an unstable soil unit, this potential impact is considered **significant**.

11.5.3.4.7 Impact 11-7d: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

Construction of levees and other embankments as a result of flood risk reduction actions encouraged by the Proposed Project (Section 11.5.3.4) may result in an increased occurrence of landslides, typically shallow surficial failures on fill slopes. Landslides on fill embankments can occur especially during wet months, and also when seismic shaking events occur. It is not known at this time what types or where construction of specific flood risk reduction projects would occur. However, a project that involves similar levee construction actions is the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010).

In the EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR did not evaluate the potential impacts due to landslides but found that other geology-related impacts were either less than significant or could be mitigated to less than significant levels. In addition to levee construction and levee repairs the Delta Plan encourages implementation of dredging to reduce flood risk including hydraulic dredging in the Sacramento Deep Water Ship Channel and Stockton Deep Water Ship Channel Dredging. The Draft Supplemental EIS/Subsequent EIR for the Sacramento River Deep Water Ship Channel (USACE and Port of West Sacramento 2011), a project that is both encouraged by the Delta Plan Program Draft EIR's Proposed Project and serves as an example of dredging projects, analyzed proposed dredging activities and concluded that the Sacramento River Deep Water Ship Channel's proposed project would not destabilize or undermine levee or berm stability from placement of dredged material.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for construction and dredging activities associated with named projects or projects encouraged by the Proposed Project to result in an increased occurrence of landslides, this potential impact is considered **significant**.

11.5.3.4.8 Impact 11-8d: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

It is unclear at this time how implementation of the Proposed Project would result in construction and operations of flood risk reduction projects, including the location, number, size, methods, and duration of construction activities. However, the flood risk reduction projects and actions identified in Section 11.5.3.4 would be unlikely to result in permanent facilities that would require an on-site wastewater treatment system for the disposal of wastewater.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because flood risk reduction projects and actions would be unlikely to result in permanent facilities that would require an onsite wastewater treatment system, this potential impact is likely to be **less than significant**.

11.5.3.4.9 Impact 11-9d: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

Flood risk reduction actions/ projects encouraged by the Proposed Project (Section 11.5.3.4) could be constructed on soils with high levels of organic matter (such as peat or muck soils). Structural problems could result over time because these soils do not provide stable bearing surfaces. High organic matter soils tend to settle and may decrease in volume as organic matter is oxidized. If not accounted for in project design, soils with high organic matter levels could degrade structural integrity of facilities.

It is not known at this time what types or where construction of specific Flood Risk Reduction projects would occur. However, a project that involves similar hydraulic dredging and levee construction actions is the North Delta Flood Control and Ecosystem Restoration Project, which was discussed in the ecosystem restoration subsection (Section 11.5.3.2.1). In the EIR for the North Delta Flood Control and Ecosystem Restoration Project (DWR 2010), DWR found that placement of material (from levee degradation, breaching, or dredging) or imported soil for levee reinforcement, modification, or construction in area with peat soils could result in consolidation of these soils and land subsidence. Potential impacts associated with any increase in the potential for land subsidence were considered less than significant because project design and construction measures would consider the potential for land subsidence and appropriate levee standards and design criteria would be incorporated and approved by FEMA.

The Draft Supplemental EIS/Subsequent EIR for the Sacramento River Deep Water Ship Channel (USACE and Port of West Sacramento 2011), a project that is both encouraged by the Proposed Project and serves as an example of dredging projects, analyzed proposed dredging activities and concluded that the Sacramento River Deep Water Ship Channel's proposed project would not destabilize or undermine levee or berm stability from placement of dredged material because geotechnical investigations would be completed to ensure that levees and berms would not be impacted from the placement of dredged material.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for levees and other facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on high organic matter soils, this potential impact is considered **significant**.

11.5.3.5 Protection and Enhancement of Delta as an Evolving Place

As described in Sections 2A and 2B, the Delta Plan does not direct the construction of specific projects, nor would projects be implemented under the direct authority of the Delta Stewardship Council. However, the Delta Plan seeks to protect and enhance the Delta as an evolving place by encouraging various actions and projects, which if taken could lead to completion, construction and/or operation of associated projects. Features of such actions and could include the following:

- Gateways, bike lanes, parks, trails, and marinas and facilities to support wildlife viewing, angling, and hunting opportunities
- Additional retail and restaurants in legacy towns to support tourism

The number and location of all potential projects that could be implemented is not currently known. However, three possible projects known to some degree and named in the Delta Plan are the new State Parks at Barker Slough, Elkhorn Basin, and in the southern Delta.

11.5.3.5.1 Impact 11-1e: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

Community gateways, bike lanes, trails, and facilities to support wildlife viewing, angling, and hunting could be established in the Delta to protect and enhance it as an evolving place (see Section 18 [Recreation] for additional description of these facilities and activities). The construction and use of these recreational facilities encouraged by the Proposed Project could expose people or structures to adverse effects involving the rupture of known earthquake faults. Actions or projects the Delta Plan is encouraging (Section 11.5.3.5) could be constructed anywhere in the Delta.

As described in prior sections, there are two known earthquake faults with surface expression that cross the Project Area and the presence of these faults may impact construction activities. Structural setbacks may be required where active fault traces are present. Special design considerations may also be required in proximity to these faults to mitigate potential high ground acceleration. It should be noted that other active faults are present at depth within the Project area. These are known as blind thrust faults, and they have no surface expression. Potential impacts associated with these blind thrust faults do not include surface rupture, but are instead limited to strong ground motion, and are discussed in Section 11.5.3.5.2.

Although the specific impacts of many of these projects, if they go forward, are yet to be determined, projects recently evaluated under CEQA with characteristics similar to those described above for protection and enhancement of the Delta as an evolving place provide perspective on the types of impacts that might result. In the program-level EIR for the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and Recreation 2008), a project analogous to those encouraged in the Delta, the lead agency found that the proposed park is not located within any currently established Alquist-Priolo Earthquake Fault Zone and that any structure associated with the project would be required to meet all applicable seismic safety standards and regulations. Therefore, it was concluded that the project would result in less than significant impacts related to seismic activity.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for recreational facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on a known earthquake fault, this potential impact is considered **significant**.

11.5.3.5.2 Impact 11-2e: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

The construction and use of recreational facilities encouraged by the Proposed Project could expose people or structures to adverse effects involving the rupture of known earthquake faults. Actions or projects the Delta Plan is encouraging (Section 11.5.3.5) could be constructed anywhere in the Delta.

Due to the presence of nearby faults, including: a) known active faults within the Project Area that have surface expression; b) known active faults within the Project Area that do not have surface expression (such as the Midland and Vernalis blind thrust faults); and c) known regional active faults in the vicinity of the project area that have or do not have surface expression, strong ground motion during seismic events can and will occur within the Project Area in the future. The effects of strong ground motion (shaking) are many, including structural deformation and failure of structures such as community gateways, bike lanes, trails, and facilities to support wildlife viewing, angling, and hunting.

As described above for Impact 11-1e, the program-level EIR for the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and Recreation 2008), found that the proposed park is not located within any currently established Alquist-Priolo Earthquake Fault Zone and that any structure associated with the project would be required to meet all applicable seismic safety standards and regulations. Therefore, it was concluded that the project would result in less than significant impacts related to seismic activity.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for recreational facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located in areas where strong ground motion during seismic events can and will occur, this potential impact is considered **significant**.

11.5.3.5.3 Impact 11-3e: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil That Is Unstable, or That Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction or Collapse

The construction of recreational facilities described above in Section 11.5.3.5 could require the use of heavy equipment, such as excavators, graders, scrapers, bulldozers, and backhoes, along with haul trucks that would be used to move borrow and/or spoils and other materials. Areas of unstable soils, with the potential for lateral spreading, subsidence, liquefaction, or collapse, could cause unsafe working conditions. Construction activities could occur in areas underlain by soft or loose soils, where high groundwater or seepage may be present and on sloping grounds. In addition, operation of these facilities could expose people to unsafe conditions associated with unstable soils that could result in loss of bearing value, lateral spreading, subsidence, liquefaction, or collapse.

Although the specific impacts of many of these projects, if they go forward, are yet to be determined, projects recently evaluated under CEQA with characteristics similar to those described above for protection and enhancement of the Delta as an evolving place provide perspective on the types of impacts that might result. For example, the final EIR for the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation 2008) and the program-level EIR for the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and Recreation 2008) describe some of the types of impacts associated with park development and construction of recreational facilities.

In the EIR for the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation), the lead agency found that because potential seismic-related impacts would be avoided or minimized through provisions of the California Code of Regulations, Title 24 (California Building Code) and potential erosion would be addressed through park plan goals and guidelines, implementation of the project would result in less than significant impacts to geology and soils. San Diego County found that the proposed San Luis Rey River Park would not be located on soils susceptible to liquefaction and impacts related to liquefaction would be less than significant.

Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. Geotechnical investigations would be conducted during design at and near the locations of facilities to the depths necessary to characterize the subsurface conditions. The information would be used to determine foundation criteria that meet the settlement and bearing-capacity requirements for structures. However, because of the potential for recreational facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on a geologic unit or soil that is unstable or could become unstable as a result of the project or construction activities, this potential impact is considered **significant**.

11.5.3.5.4 Impact 11-4e: Substantial Soil Erosion or the Loss of Topsoil

The construction of recreational facilities described above in Section 11.5.3.5 could disturb soil through excavating, earth moving, grading, filling, and stockpiling of soil material, and these disturbed soils could be susceptible to wind and water erosion. Without implementation of appropriate management measures, substantial erosion and loss of topsoil could occur. Operation of facilities encouraged by the Proposed Project could result in erosional loss of topsoil where surface drainage conditions are modified.

As described above in Section 11.5.3.1.4, any construction project more than 1 acre in size would be required develop and implement an effective combination of erosion and sediment control BMPs to manage erosion and topsoil loss. Construction and post-construction BMPs would be identified in the project's SWPPP.

It is not known at this time exactly what types or where construction of specific enhancement actions/ projects would occur in the Delta. However, there are ongoing projects that are similar to these park projects and that would be comparable to the general types of Delta-enhancement projects listed above. One of these ongoing projects that has undergone project-specific environmental review is the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation 2008).

In the EIR for the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation), the lead agency found that ground-disturbing activities could result in erosion, However, consistent with the park plan's goals and guidelines, the project would restore riparian vegetation, which would aid in minimizing erosion. Additionally, the proposed facilities would be designed and constructed with the use of BMPs, including measures specified in erosion-control plans. Therefore, it was concluded that implementation of the project would result in less than significant impacts related to soil erosion.

Because Delta enhancement projects and actions encouraged by the Delta Plan would be required to comply with local requirements and State regulations, and would develop and implement a site-specific SWPPP, soil erosion and topsoil loss would likely be minimized. The details of many of the aspects of these projects, however, are not currently known, and it is possible that significant soils loss could occur. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies of these potential projects. However, because of the potential for substantial soil loss or loss of topsoil as a result of named projects or projects encouraged by the Proposed Project, this potential impact is considered **significant**.

11.5.3.5.5 Impact 11-5e: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

Construction-related grading activities for the types of projects identified in Section 11.5.3.5 could expose or reduce the vertical distance to expansive clays in the subsurface. The potential construction-related geology impacts would be similar to those described in Section 11.5.3.1.5 for facilities to improve water supply reliability. Expansive clays can cause heaving, particularly differential heaving that can be damaging to improvements.

It is not known at this time exactly what types or where construction of specific enhancement actions/ projects would occur in the Delta. However, there are ongoing projects that are similar to these park projects and that would be comparable to the general types of Delta-enhancement projects noted above. These ongoing projects which have undergone project-specific environmental review are the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation 2008) and the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and Recreation 2008). Neither of the project's EIR documents analyzed specific impacts related to expansive soils.

Because of the uncertainties underlying this program-level assessment, impacts relating to the presence of expansive soils in the Delta cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for recreational facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on expansive or corrosive soils, this potential impact is considered **significant**.

11.5.3.5.6 Impact 11-6e: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

Operation of facilities constructed as a result of projects encouraged by the Proposed Project (Section 11.5.3.5) could result in the occurrence of nuisance water (formation of surface springs and seeps) in adjacent areas due to leakage of such facilities if such facilities resulted in the impoundment or redirection of surface water. Nuisance water due to leakage could result in formation of areas of unstable soils and potentially result in on- or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse.

It is not known at this time exactly what types or where construction of specific enhancement actions/ projects would occur in the Delta. However, there are ongoing projects that are similar to these park projects and that would be comparable to the general types of Delta-enhancement projects listed above. These ongoing projects which have undergone project-specific environmental review are the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation 2008) and the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and Recreation 2008). In both cases, the lead agency did not specifically analyze the potential for impacts from nuisance water.

Because of the uncertainties underlying this program-level assessment, nuisance water impacts in the Delta cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for recreational facilities constructed as a result of named projects or projects encouraged by the Proposed Project to result in nuisance water and potentially create an unstable soil unit, this potential impact is considered **significant**.

11.5.3.5.7 Impact 11-7e: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

Construction of projects to protect and enhance the Delta as an evolving place (Section 11.5.3.5) could include levee modification and construction of embankments, which may result in an increased occurrence of landslides, typically shallow surficial failures on fill slopes. Landslides on fill embankments can occur especially during wet months, and also when seismic shaking events occur.

It is not known at this time exactly what types or where construction of specific enhancement actions/ projects would occur in the Delta. However, there are ongoing projects that are similar to these park projects and that would be comparable to the general types of Delta-enhancement projects listed above. These ongoing projects which have undergone project-specific environmental review are the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation) and the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and Recreation 2008).

In the EIR for the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation), the lead agency found that slopes on the project site were generally less than 2 percent and landslides were determined not to be a hazard. San Diego County found that the proposed San Luis Rey River Park would likely not grade or disturb any steep slope along the higher hills in the proposed park, nor would it affect river bank slopes except at proposed bridge crossings. Much of the proposed park would be left undisturbed and development sites would be relatively level and require little grading. Therefore, potential impacts due to landslides were determined to be less than significant.

Because of the uncertainties underlying this program-level assessment, impacts relating to landslides in the Delta cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for construction activities associated with named projects or projects encouraged by the Proposed Project to result in an increased occurrence of landslides, this potential impact is considered **significant**.

11.5.3.5.8 Impact 11-8e: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

Construction-related activities for the types of projects identified in Section 11.5.3.5 would generally take place within the Delta, as described in Section 2A, Proposed Project and Alternatives. These facilities may be sited in locations far from municipalities with sewer connections, and therefore could potentially require an onsite wastewater treatment system for the disposal of wastewater during project operation. If permanent facilities are constructed in remote locations, a septic tank or alternative wastewater disposal system would have to be installed for use during operation.

Based on the soil associations found within the Delta and Suisun Marsh, it is expected that the majority of the soils in this area will have some limitations for onsite wastewater disposal. The majority of the soils have a slow permeability, a shallow duripan or hardpan, or high potential for flooding or ponding, preventing the soil from properly treating effluent. Because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, impacts could be significant without appropriate project design and/or mitigation.

It is not known at this time what types or where construction of specific Delta as evolving place type projects would occur. However, the Delta Plan encourages implementation of the Barker Slough and Elkhorn Basin State Parks and a new park somewhere in the southern Delta, There are ongoing projects that are similar to these park projects and that would be comparable to the general types of Delta-enhancing projects listed above. These ongoing projects have undergone project-specific environmental review in the Bidwell-Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project EIR (The Nature Conservancy and California Department of Parks and Recreation 2008) and San Luis Rey River Park Master Plan EIR (San Diego County Department of Parks and Recreation 2008).

In the Bidwell-Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project EIR (The Nature Conservancy and California Department of Parks and Recreation), the proposed project included a new septic system/leachfield to service the restroom/shower building that would be located in an area where annual flooding is not anticipated. Guidelines were provided for construction and maintenance of restroom facilities and septic systems in areas prone to flooding. Because a septic system permit would be required from Butte County, which would include a soil profile and percolation test, and with consideration to the guidelines provided with respect to flooding, impacts related to soil suitability for supporting septic systems were less than significant. The San Luis Rey River Park Master Plan EIR (San Diego County Department of Parks and Recreation 2008) did not analyze potential impacts related to suitability of soils to support septic systems, but vault toilets that store sewage in a vault below the bathroom were identified as an alternative if sewage treatment capacity was not available for the proposed park.

Because of the uncertainties underlying this program-level assessment, impacts of soils incapable for supporting alternative wastewater systems in the Delta, Delta watershed, or areas outside the Delta that use Delta water cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because soils in extensive areas within the Delta and Suisun Marsh appear to have limited suitability for supporting septic systems, this potential impact is considered **significant**.

11.5.3.5.9 Impact 11-9e: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

Facilities described above in Section 11.5.3.5 could be constructed on soils with high levels of organic matter (such as peat or muck soils). Structural problems could result over time because these soils do not provide stable bearing surfaces. High organic matter soils tend to settle and may decrease in volume as organic matter is oxidized. If not accounted for in project design, soils with high organic matter levels could degrade structural integrity of facilities.

It is not known at this time exactly what types or where construction of specific enhancement actions/ projects would occur in the Delta. However, there are ongoing projects that are similar to these park projects and that would be comparable to the general types of Delta-enhancement projects listed above. These ongoing projects which have undergone project-specific environmental review are the Bidwell–Sacramento River State Park Habitat Restoration and Outdoor Recreation Facilities Development Project (The Nature Conservancy and California Department of Parks and Recreation 2008) and the development of San Luis Rey River Park in northern San Diego County (San Diego County Department of Parks and

Recreation 2008). In both cases, the lead agency did not specifically analyze the potential for impacts due to high organic matter soils, but found that all identified geologic and seismic impacts were less than significant.

Because of the uncertainties underlying this program-level assessment, impacts due to construction activities on high organic matter soils in the Delta cannot be accurately quantified. Project-level impacts would be addressed in future site-specific environmental analysis conducted at the time such projects are proposed by lead agencies. However, because of the potential for recreational facilities constructed as a result of named projects or projects encouraged by the Proposed Project to be located on peat or other high organic matter soils (soil that is unstable, or that would become unstable as a result of the project), this potential impact is considered **significant**.

11.5.3.6 Mitigation Measures

Any covered action that would have one or more of the significant environmental impacts listed above shall incorporate the following features and/or requirements related to such impacts.

With regard to covered actions implemented under the Delta Plan, these mitigation measures will reduce the impacts of the Proposed Project. Project-level analysis by the agency proposing the covered action will determine whether the measures are sufficient to reduce those impacts to a less-than-significant level. Generally speaking, many of these measures are commonly employed to minimize the severity of an impact and in many cases would reduce impacts to a less-than-significant level, as discussed below in more detail.

With regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Council. Those agencies can and should adopt these measures as part of their approval of such actions, but the Council does not have the authority to require their adoption. Therefore, significant impacts of noncovered actions could remain **significant and unavoidable**.

How mitigation measures in this EIR relate to covered and noncovered actions is discussed in more detail in Section 2B, Introduction to Resource Sections.

11.5.3.6.1 Mitigation Measure 11-1

The following mitigation measures would reduce the effects of Impact 11-1a, Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault:

- For construction that occurs in an Alquist-Priolo Special Studies Zone, a determination must be made by a licensed practitioner (California Certified Engineering Geologist) that no fault traces are present within the building footprint of any structure intended for human occupancy. The standard of care for such determinations includes direct examination of potentially affected subsurface materials (soil and/or bedrock) by logging of subsurface trenches. Uncertainties regarding the exact locations of future ground ruptures associated with such determinations generally are resolved by providing a minimum setback of 50 feet from any known surface trace of an active fault. For critical structures, such as hospitals, dams, and emergency facilities, more stringent mitigation measures are required, including but not limited to greater structural setbacks and heavier reinforcement against strong ground motion, in compliance not only with California regulations but in many cases in compliance with additional Federal regulations.

- Lead agencies shall ensure that geotechnical design recommendations are included in the design of facilities and construction specifications to minimize the potential impacts from seismic events and the presence of adverse soil conditions. Recommended measures to address adverse conditions shall conform to applicable design codes, guidelines, and standards.

These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant impacts due to the rupture of a known earthquake faults to less-than-significant levels. Implementation of these mitigation measures would reduce the significance of impacts; however, due to the potential for facilities constructed to be located on a known earthquake fault, this potential impact would remain **significant.**

11.5.3.6.2 Mitigation Measure 11-2

The following mitigation measures would reduce the effects of Impact 11-2a, Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking:

- Require adherence, at minimum, to the precepts of the current approved version of the International Building Code (IBC). Included in the IBC are measures for mitigation of the impacts of strong ground motion on constructed works. In addition to the California –required conformance with the IBC, for critical structures, such as dams (including levees), hospitals, and emergency facilities, additional construction requirements are codified in federal statutes and the regulations of various federal agencies. Lead agencies will, by force of law, require conformance with these codified mitigation measures.

These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant strong ground motion associated with seismic shaking impacts to less-than-significant levels. Implementation of these mitigation measures would reduce the significance of these impacts by requiring compliance to the mitigation measures in the current approved version of the IBC. In some cases it will not be feasible to comply with these regulations because of the probability of projects to be located in areas where strong ground motion during seismic events can and will occur. For these reasons, impacts related to strong ground motion associated with seismic shaking would remain **significant**.

11.5.3.6.3 Mitigation Measure 11-3

The following mitigation measures would reduce the effects of Impact 11-3a, Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil That Is Unstable, or That Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction or Collapse:

- For projects that would result in significant or potentially significant grading operations, a geotechnical investigation shall be performed and a geotechnical report prepared.
  The geotechnical report shall include a quantitative analysis to determine whether excavation or fill placement would result in a potential for damage due to soil subsidence during and/or after construction. Project designs shall incorporate measures to reduce the potential damage to an insignificant level, including but not limited to removal and recompaction of existing soils susceptible to subsidence, ground improvement (such as densification by compaction or grouting, soil cementation), and reinforcement of structural components to resist deformation due to subsidence. The site-specific potential for and magnitude of cyclic seismic loading shall be analyzed in the assessment of subsidence for specific projects.

- A geotechnical investigation shall be performed by an appropriately licensed professional engineer and/or geologist to determine the presence and thickness of potentially liquefiable sands that could result in loss of bearing value during seismic shaking events. Project designs shall incorporate measures to mitigate the potential damage to an insignificant level, including but not limited to ground improvement (such as grouting or soil cementation), surcharge loading by placement of fill, excavation, soil mixing with non-liquefiable finer-grained materials and replacement of liquefiable materials at shallow depths, and reinforcement of structural components to resist deformation due to liquefaction. An analysis of site-specific probable and credible seismic acceleration values, in accordance with current applicable standards of care, shall be performed to provide for suitable project design.

- For projects that would result in construction of wells intended for groundwater extraction, a hydrogeological/geotechnical investigation shall be performed in accordance with the current standards of care for such work by an appropriate licensed professional engineer or geologist to identify and quantify the potential for groundwater extraction-induced subsidence. The study shall include an analysis of existing conditions and modeling of future conditions to assess the potential for aquifer compaction/consolidation.
- For projects that would result in construction of surface reservoirs and canals a hydrogeological/geotechnical investigation shall be performed by a licensed professional engineer or geologist to identify and quantify the potential for seeps and springs to develop in areas adjacent to the proposed improvements and to propose mitigation measures. Mitigation of such seepage could include, without limitation, additives to concrete that reduce its permeability, construction of impervious liner systems, and design and construction of subdrainage (passive control) or dewatering systems (active control).

Geotechnical investigations and preparation of geotechnical reports shall be performed in the responsible care of California licensed geotechnical professionals including professional civil engineers, certified geotechnical engineers, professional geologists, certified engineering geologists, and certified hydrogeologists, all of whom should be practicing within the current standards of care for such work.

These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant impacts due to unstable soils to less-than-significant levels. Implementation of these mitigation measures would provide the information needed to design and construct facilities that should be able to withstand unstable soils. In some cases it will not be feasible to design the facility to withstand such forces due to cost, etc. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, impacts due to unstable geologic units and soils would remain **significant**.

11.5.3.6.4 Mitigation Measure 11-4

The following mitigation measures would reduce the effects of Impact 11-4a, Substantial Soil Erosion or the Loss of Topsoil:

- Any covered action that would have significant soil erosion and topsoil loss impacts (Impact 11-4) shall incorporate specific measures for future projects that would expand the use of BMPs or optional erosion control measures listed in the SWPPPs. The SWPPP shall identify an effective combination of BMPs to reduce erosion during construction and to prevent erosion during operation. Examples of typical BMPs include:
  - Erosion control measures such as silt fencing, sand bags, straw bales and mats, and rice straw wattles shall be placed to reduce erosion and capture sediment. Straw used for erosion control shall be new cereal grain straw derived from rice, wheat, or barley; free of mold and noxious weed seed; and neither derived from dry-farmed crops nor previously used for stable bedding. Clearance shall be obtained from the County Agricultural Commissioner before straw obtained from outside the county is delivered to the work site. Monitoring requirements of the

newly revised General Construction Permit shall be implemented, and more effective BMPs shall be identified and installed if runoff samples indicate excessive turbidity.

- During construction activities, topsoil shall be removed, stockpiled, and saved for reapplication following completion of construction. The top 6 inches shall be salvaged and reapplied to a comparable thickness. Soil material shall be placed in a manner that minimizes compaction and promotes plant reestablishment.
- If catch basins are used for sediment capture, the site shall be graded to ensure stormwater runoff flows into the basins, and basins shall be designed for the appropriate storm interval as provided in the General Construction Permit.
- Temporary work areas shall be surfaced with a compacted layer of well-graded gravel. They may be covered with a thin asphalt binder. Where expansive or compressible soils are present in temporary work areas, construction trailers shall be supported with concrete pads or footings.
- Dust control shall conform to all federal, State, and local requirements and may include use of water trucks, street sweepers, or other methods described in the SWPPP.
- Spoils shall be placed in 12-inch-thick loose lifts and compacted to reduce erosion and minimize future subsidence. Placement of peat spoils shall be on agricultural land where possible. Following construction, spoils sites shall be restored to avoid erosion.

♦ These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant soil erosion and topsoil loss impacts to less-than-significant levels. Implementation of these mitigation measures would reduce the potential for soil erosion and loss of topsoil due to project construction activities. In some cases it will not be feasible to prevent significant soil erosion and loss of topsoil due to cost, construction schedule, soil type, and soil behavior. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, construction related soil erosion and loss of topsoil impacts would remain **significant**.

11.5.3.6.5 Mitigation Measure 11-5

The following mitigation measures would reduce the effects of Impact 11-5a, Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils:

♦ In areas where expansive clays exist, a hydrogeological/geotechnical investigation shall be performed by a licensed professional engineer or geologist to identify and quantify the potential for expansion, particularly differential expansion of clayey soils due to leakage and saturation beneath new improvements. Measures could include, but are not limited to removal and recompaction of problematic expansive soils, soil stabilization, and/or reinforcement of constructed improvements to resist deformation due to expansion of subsurface soils.

♦ These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant impacts due to expansive soils to less-than-significant levels. Implementation of these mitigation measures would reduce the potential for impacts due to expansive soils. In some cases it will not be feasible to mitigate for expansive soils because of cost, depth of expansive soils, construction schedule, unexpected presence of expansive soils, and project design restrictions. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, potential impacts due to expansive soils would remain **significant.**

11.5.3.6.6 Mitigation Measure 11-6

The following mitigation measures would reduce the effects of Impact 11-6a, Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage):

- For projects that would result in construction of canals, storage reservoirs and other surface impoundments, project design shall provide for protection from leakage to the subsurface. Measures could include, but are not limited to rendering concrete less permeable by specifying concrete additives such as bentonite, design of impermeable liner systems, design of leakage collection and recovery systems, and construction of impermeable subsurface cutoff walls.
- These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant nuisance water impacts to less-than-significant levels. Implementation of these mitigation measures would reduce the potential for operation of projects to result in nuisance water in adjacent areas due to leakage. In some cases it will not be feasible to comply with the mitigation measures due to cost constraints. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, impacts associated with nuisance water in adjacent areas due to leakage would remain **significant**.

For Impact 11-6b, the following mitigation measures would apply.

- For ecosystem restoration projects that might cause subsurface seepage of nuisance water onto adjacent lands:
  - Perform seepage monitoring studies by measuring the level of shallow groundwater in the adjacent soils, to evaluate the baseline conditions. Continue monitoring for seepage during and after the project implementation.
  - Develop a seepage monitoring plan if subsurface seepage constitutes nuisance water to the adjacent land.
  - Implement seepage control measures if adjacent land is not useable, such as installing subsurface agricultural drainage systems to avoid raising water levels into crop root zones. Cutoff walls and pumping wells can also be used to mitigate for the occurrence of subsurface nuisance water.

11.5.3.6.7 Mitigation Measure 11-7

The following mitigation measures would reduce the effects of Impact 11-7a, Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides:

- For projects that would result in construction of levees, surface impoundments and other fill embankments project design shall incorporate fill placement in accordance with local and State regulations and in accordance with the prevailing standards of care for such work. Measures could include, but are not limited to blending of soils most susceptible to landsliding with soils having higher cohesion characteristics, installation of slope stabilization measures, designing top-of-slope berms or v-ditches, terrace drains and other surface runoff control measures, and designing slopes at lower inclinations.

- These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant impacts due to landslides to less-than-significant levels. Implementation of these mitigation measures would reduce the potential for risks due to landslides. In some cases it will not be feasible to apply soil or slope improvements due to cost or space constraints. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, impacts due to potential landslides would remain **significant**.

11.5.3.6.8 Mitigation Measure 11-8

The following mitigation measure would reduce the effects of Impact 11-8a, Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water:

- A geotechnical investigation shall be performed and a geotechnical report prepared. The geotechnical report shall include a quantitative analysis to determine whether on-site soils would be suitable for an on-site wastewater treatment system. If it is determined that the soil could not support a conventional on-site treatment system, non-conventional systems shall be analyzed. Potential alternative systems include (SWRCB, 2011):
    - Containment systems that do not generate waste
    - Anoxic and anaerobic systems
    - Attached and suspended growth aerobic treatment systems
    - Natural treatment systems
    - Disinfection systems
    - Monitoring control systems

These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant wastewater impacts to less-than-significant levels. Implementation of these mitigation measures would reduce the significance of having soils incapable of supporting the use of traditional septic systems where sewers are not available for the disposal of wastewater. In some cases it will not be feasible to provide alternative wastewater disposal systems due to space constraints, lack of a service provider, and/or cost. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, wastewater disposal impacts would remain **significant.**

11.5.3.6.9 Mitigation Measure 11-9

The following mitigation measures would reduce the effects of Impact 11-9a, Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils:

- For projects that would result in significant or potentially significant risk to structures due to the presence of highly organic soils, lead agencies shall require geotechnical evaluation prior to construction to identify measures to mitigate organic soils. The following measures may be considered:
    - Over-excavation and import of suitable fill material
    - Structural reinforcement of constructed works to resist deformation

- Construction of structural supports below the depth of highly organic soils into materials with suitable bearing strength

These mitigation measures are commonly employed on a variety of construction projects. In many cases, they reduce significant impacts due to construction on high organic matter soils to less-than-significant levels. Implementation of these mitigation measures would reduce the potential for impacts due to construction on high organic matter soils. In some cases it will not be feasible to comply with the measures listed above due to cost, lack of proper materials, or design constraints. Moreover, as discussed above, with regard to actions taken by other agencies on the basis of Delta Plan recommendations (i.e., activities that are not covered actions), the implementation and enforcement of these measures would be within the responsibility and jurisdiction of public agencies other than the Delta Stewardship Council. For these reasons, impacts due to high organic matter soils would remain **significant**.

11.5.4 No Project Alternative

As described in Section 2A, Proposed Project and Alternatives, the No Project Alternative is based on the continuation of existing plans and policies and the continued operation of existing facilities into the future and permitted and funded projects. Seven ongoing projects have been identified as part of the No Project Alternative. The list of projects included in the No Project Alternative is presented in Table 2-2.

The No Project Alternative includes various water supply projects and one ecosystem enhancement project, as described in Section 2A, Proposed Project and Alternatives. These generally would have the same types of geology-related impacts as would occur under the Proposed Project. However, the Delta Plan would not be in place to encourage various other projects to move forward. To the extent the absence of the Delta Plan results in those projects not being undertaken, there would be no geology- or soil-related impacts associated with them.

Relative to the Proposed Project, the No Project Alternative would result in fewer actions and projects to improve water supply reliability, restore the Delta ecosystem, improve water quality, reduce flood risk, and protect and enhance the Delta as an evolving place. Overall, the reduced number of projects and actions under the No Project Alternative would reduce the geology- and soil-related impacts resulting from construction and operation of those projects. In addition to a general reduction in the number of projects with relatively small construction footprints, the large-scale surface water storage facilities and increased levee modification and maintenance encouraged under the Proposed Project would not move forward under the No Project Alternative, and the impacts associated with these projects would not occur. Similarly, fewer ecosystem restoration projects would proceed under the No Project Alternative, resulting in fewer construction-related geology and soils impacts.

Overall, the adverse impacts related to geology and soils resulting from the No Project Alternative would be **less than** those under the Proposed Project.

11.5.5 Alternative 1A

Under Alternative 1A, the construction and operation of surface water projects (water intakes, treatment and conveyance facilities, and reservoirs) would be the same as under the Proposed Project. As described in Section 2A, Proposed Project and Alternatives, there would be fewer groundwater projects (wells, wellhead treatment, conveyance facilities), ocean desalination projects, recycled wastewater and stormwater projects (treatment and conveyance facilities) compared with the Proposed Project. Water transfers and water use efficiency and conservation programs also would be reduced relative to the Proposed Project, but these activities would not be expected to have geology- or soil-related impacts under any of the alternatives.

Projects to restore the Delta ecosystem would be reduced relative to the Proposed Project, and the implementation of flow objectives that could lead to a more natural flow regime in the Delta would not be accelerated. Ecosystem stressor management activities and invasive species management (including removal of invasive vegetation) would be the same as described for the Proposed Project.

Projects and actions to improve water quality would be the same as under the Proposed Project. Flood risk reduction projects would place less emphasis than the Proposed Project on levee maintenance and modification for levees that protect agricultural land and more emphasis on levees that protect water supply corridors, which could result in an overall reduction in these activities. Projects to protect and enhance the Delta as an evolving place would be the same as for the Proposed Project.

11.5.5.1.1 Impact 11-1: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault.

The exposure of people or structures to potential substantial adverse effects involving rupture of a known earthquake fault would be reduced under Alternative 1A relative to the Proposed Project because of the reduction in projects related to water supply reliability, such as groundwater projects, ocean desalination projects, recycled wastewater and stormwater projects. Impacts associated with ecosystem restoration and flood risk reduction also would be reduced because fewer of those activities would be conducted or facilities constructed.

Alternative 1A could reduce the potential for significant adverse impacts relative to the Proposed Project. However, the alternative's potential geology-related impacts associated with known earthquake faults are considered significant because the locations and details of projects and actions that might be constructed are not currently known.

Overall, significant adverse impacts associated with known earthquake faults under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with known earthquake faults under Alternative 1A would be **significant**.

11.5.5.1.2 Impact 11-2: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

The exposure of people or structures to potential substantial adverse effects involving strong ground motion associated with seismic shaking would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative's potential impact associated with strong ground motion and seismic shaking is considered significant.

Overall, significant impacts associated with strong ground motion and seismic shaking under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with strong ground motion and seismic shaking under Alternative 1A would be **significant**.

11.5.5.1.3 Impact 11-3: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil that Is Unstable, or that Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction, or Collapse

The potential for construction and operation of projects to occur on unstable geologic units or soils would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative's potential impact associated with unstable geologic units and soils is considered significant.

Overall, significant impacts associated with unstable geologic units and soils under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with unstable geologic units and soils under Alternative 1A would be **significant**.

11.5.5.1.4 Impact 11-4: Substantial Soil Erosion or the Loss of Topsoil

The potential for construction and operation of projects to result in substantial soil erosion or the loss of topsoil would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative's potential impact associated with soil erosion soil is considered significant.

Overall, significant impacts associated with substantial soil erosion or the loss of topsoil under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with substantial soil erosion or the loss of topsoil under Alternative 1A would be **significant**.

11.5.5.1.5 Impact 11-5: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

The potential for construction of projects on expansive soils would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative's potential impact associated with expansive soils is considered significant.

Overall, significant impacts associated with expansive soils under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with expansive soils under Alternative 1A would be **significant**.

11.5.5.1.6 Impact 11-6: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

The potential for operation of projects to result in nuisance water would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed and operated are not currently known, the alternative's potential impact associated with nuisance water is considered significant.

Overall, significant impacts associated with nuisance water under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with nuisance water under Alternative 1A would be **significant**.

11.5.5.1.7 Impact 11-7: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

The exposure of people or structures to potential substantial adverse effects involving landslides would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative’s potential impact associated with landslides is considered significant.

Overall, significant impacts associated with landslides under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with landslides under Alternative 1A would be **significant**.

11.5.5.1.8 Impact 11-8: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

The potential for construction of projects that require the use of septic tanks would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative’s potential impact associated with soils incapable of adequately supporting the use of septic tanks is considered significant.

Overall, significant impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 1A would be **significant**.

11.5.5.1.9 Impact 11-9: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

The potential for construction of projects on high organic matter soils would be reduced relative to the Proposed Project under Alternative 1A for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the alternative’s potential impact associated with high organic matter soils is considered significant.

Overall, significant impacts associated with high organic matter soils under Alternative 1A would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with high organic matter soils under Alternative 1A would be **significant**.

11.5.5.2 Mitigation Measures

Mitigation measures for impacts associated with Alternative 1A would be the same as those described for the Proposed Project in Sections 11.5.3.6.1 (Mitigation Measure 11-1) through 11.5.3.6.9 (Mitigation Measure 11-9). Because it is not known whether the mitigation measures listed above would reduce impacts to a less-than-significant level for Alternative 1A, these potential impacts are considered **significant and unavoidable**.

11.5.6 Alternative 1B

Under Alternative 1B, the construction and operation of surface water projects (water intakes, treatment and conveyance facilities, and reservoirs) would be the same as under the Proposed Project. As described in Section 2A, Proposed Project and Alternatives, there would be fewer groundwater projects (wells, wellhead treatment, conveyance facilities), recycled wastewater and stormwater projects (treatment and conveyance facilities) compared with the Proposed Project. Water transfers and water use efficiency and conservation programs also would be reduced relative to the Proposed Project, but these activities would not be expected to have geology- or soil-related impacts under any of the alternatives. There would be no ocean desalination projects.

Projects to restore the Delta ecosystem would be reduced in extent relative to the Proposed Project and would not emphasize restoration of floodplains in the lower San Joaquin River. Implementation of flow objectives would not be accelerated or include public trust considerations. Ecosystem stressor management activities and invasive species management (including removal of invasive vegetation) would be increased relative to the Proposed Project, but a variance to the USACE Levee Vegetation Policy would not be pursued (see Appendix D, Section 2.1.15). There would be no geologic hazard related impacts associated with obtaining a variance to the USACE Vegetation Policy or other levee maintenance activities because these activities would not result in construction of new facilities, although changes in levee maintenance could affect soil erosion and loss of topsoil.

Water quality improvement projects, including water treatment plants, conveyance facilities, and wells and wellhead treatment facilities, would be less emphasized relative to the Proposed Project, and greater emphasis would be placed on the construction and operation of wastewater treatment and recycle facilities and municipal stormwater treatment facilities.

Flood risk reduction would place greater emphasis on levee modification/maintenance and dredging than under the Proposed Project, but there would be no setback levees or subsidence reversal projects. Floodplain expansion projects would be fewer or less extensive, and use of reservoir reoperation would be reduced. As described in Section 2A, actions to protect and enhance the Delta as an evolving place would be consistent with the Delta Protection Commission’s Economic Sustainability Plan, but the locations for new parks, as encouraged by the Proposed Project, would not be emphasized.

11.5.6.1.1 Impact 11-1: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

The exposure of people or structures to potential substantial adverse effects involving rupture of a known earthquake fault would be reduced relative to the Proposed Project under Alternative 1B because of the reduction in projects related to water supply reliability, such as groundwater projects, ocean desalination projects, recycled wastewater and stormwater projects. Impacts associated with ecosystem restoration and flood risk reduction also would be reduced because fewer projects would be constructed.

Alternative 1B would likely reduce significant impacts relative to the Proposed Project. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential geology-related impact associated with known earthquake faults is considered significant.

Overall, significant adverse impacts associated with known earthquake faults under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with known earthquake faults under Alternative 1B would be **significant**.

11.5.6.1.2 Impact 11-2: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

The exposure of people or structures to potential substantial adverse effects involving strong ground motion associated with seismic shaking would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with strong ground motion and seismic shaking is considered significant.

Overall, significant impacts associated with strong ground motion and seismic shaking under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with strong ground motion and seismic shaking under Alternative 1B would be **significant**.

11.5.6.1.3 Impact 11-3: Projects Could Be Located on a Geologic Unit or Soil that Is Unstable, or that Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction, or Collapse

The potential for construction and operation of projects to occur on unstable geologic units or soils would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with unstable geologic units and soils is considered significant.

Overall, significant impacts associated with unstable geologic units and soils under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with unstable geologic units and soils under Alternative 1B would be **significant**.

11.5.6.1.4 Impact 11-4: Substantial Soil Erosion or the Loss of Topsoil

The potential for construction and operation of projects to result in substantial soil erosion or the loss of topsoil would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with soil erosion is considered significant.

Overall, significant impacts associated with substantial soil erosion or the loss of topsoil under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with substantial soil erosion or the loss of topsoil under Alternative 1B would be **significant**.

11.5.6.1.5 Impact 11-5: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

The potential for construction of projects on expansive soils would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with expansive soils is considered significant.

Overall, significant impacts associated with expansive soils under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with expansive soils under Alternative 1B would be **significant**.

11.5.6.1.6 Impact 11-6: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

The potential for operation of projects to result in nuisance water would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed and operated are not currently known, the potential impact associated with nuisance water is considered significant.

Overall, significant impacts associated with nuisance water under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with nuisance water under Alternative 1B would be **significant**.

11.5.6.1.7 Impact 11-7: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

The exposure of people or structures to potential substantial adverse effects involving landslides would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with landslides is considered significant.

Overall, significant impacts associated with landslides under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with landslides under Alternative 1B would be **significant**.

11.5.6.1.8 Impact 11-8: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

The potential for construction of projects that require the use of septic tanks would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with soils incapable of adequately supporting the use of septic tanks is considered significant.

Overall, significant impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 1B would be **significant**.

11.5.6.1.9 Impact 11-9: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

The potential for construction of projects on high organic matter soils would be reduced relative to the Proposed Project under Alternative 1B for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with high organic matter soils is considered significant.

Overall, significant impacts associated with high organic matter soils under Alternative 1B would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with high organic matter soils under Alternative 1B would be **significant**.

11.5.6.2 Mitigation Measures

Mitigation measures for impacts associated with Alternative 1B would be the same as those described for the Proposed Project in Sections 11.5.3.6.1 (Mitigation Measure 11-1) through 11.5.3.6.9 (Mitigation Measure 11-9). Because it is not known whether the mitigation measures listed above would reduce impacts to a less-than-significant level for Alternative 1B, these potential impacts are considered **significant and unavoidable**.

11.5.7 Alternative 2

As described in Section 2A, Proposed Project and Alternatives, Alternative 2 would place greater emphasis on groundwater, ocean desalination, water transfers, water use efficiency and conservation, and recycled water projects and less emphasis on surface water projects. The surface storage reservoirs considered under the DWR Surface Water Storage Investigation would not be encouraged; instead, surface storage in the Tulare Basin would be emphasized. Ecosystem restoration projects similar to but less extensive than those encouraged by the Proposed Project would be emphasized without the requirement to conform to the with the habitat types and elevation maps presented in the Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological 23 Management Zone and the Sacramento and San Joaquin Valley Regions (DFG 2011). Alternative 2 would emphasize the development of flow objectives that take into consideration updated flow criteria that support a more natural flow regime, water rights, and greater protection of public trust resources.

Actions to improve water quality would be similar to or greater than those under the Proposed Project, especially the treatment of wastewater and agricultural runoff. Actions to reduce flood risk under Alternative 2 would emphasize floodplain expansion and reservoir reoperation rather than levee construction and modification. The stockpiling of rock and encouragement of subsidence reversal projects would be the same as under the Proposed Project, as would actions to protect and enhance the Delta as an evolving place.

11.5.7.1.1 Impact 11-1: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

The same type of impacts from construction of water supply reliability projects would occur under Alternative 2 as described under the Proposed Project. Because Alternative 2 would not encourage surface water storage at the locations considered by the DWR Surface Water Storage Investigation, the significant impacts associated with known earthquake faults that could result from those projects would not occur. The potential impacts associated with creation of surface storage in the Tulare Basin, as emphasized under Alternative 2, would be the same as the potential risk associated with creation of surface storage described for the Proposed Project. The construction of the conveyance facilities necessary to support surface storage in the Tulare Basin, however, could increase the likelihood of encountering a known earthquake fault.

There would more wastewater treatment and agricultural runoff facilities constructed under Alternative 2 than under the Proposed Project. A similar number of the other types of water quality improvement facilities would be constructed. It is unclear whether this shift would result in more or less construction activity; therefore, the potential for projects or facilities to be located on or near an active earthquake fault are anticipated to be similar to those of the Proposed Project.

The reduction in levee construction, modification, and maintenance under Alternative 2 would reduce the potential exposure of people or structures to substantial adverse effects involving rupture of a known earthquake fault.

Alternative 2 would reduce significant impacts associated with known earthquake faults relative to the Proposed Project. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with known earthquake faults is considered significant.

Overall, significant impacts associated with known earthquake faults under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with known earthquake faults under Alternative 2 would be **significant**.

11.5.7.1.2 Impact 11-2: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

The exposure of people or structures to potential substantial adverse effects involving strong ground motion associated with seismic shaking would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with strong ground motion and seismic shaking is considered significant.

Overall, significant impacts associated with strong ground motion and seismic shaking under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with strong ground motion and seismic shaking under Alternative 2 would be **significant**.

11.5.7.1.3 Impact 11-3: Construction and Operations of Projects Could Be Located on a Geologic Unit or Soil that Is Unstable, or that Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction, or Collapse

The potential for construction and operation of projects to occur on unstable geologic units or soils would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with unstable geologic units and soils is considered significant.

Overall, significant impacts associated with unstable geologic units and soils under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with unstable geologic units and soils under Alternative 2 would be **significant**.

11.5.7.1.4 Impact 11-4: Substantial Soil Erosion or the Loss of Topsoil

The potential for construction and operation of projects to result in substantial soil erosion or the loss of topsoil would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with substantial soil erosion or the loss of topsoil is considered significant.

Overall, significant impacts associated with substantial soil erosion or the loss of topsoil under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with substantial soil erosion or the loss of topsoil under Alternative 2 would be **significant**.

11.5.7.1.5 Impact 11-5: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

The potential for construction of projects on expansive soils would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with expansive soils is considered significant.

Overall, significant impacts associated with expansive soils under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with expansive soils under Alternative 2 would be **significant**.

11.5.7.1.6 Impact 11-6: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

The potential for operation of projects to result in nuisance water would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. The emphasis on surface water storage in the Tulare Basin instead of the surface storage reservoirs considered under the DWR Surface Water Storage Investigation would shift the potential for nuisance water impacts to that region. However, because the locations and details of projects and actions that might be constructed and operated are not currently known, the potential impact associated with nuisance water is considered significant.

Overall, significant impacts associated with nuisance water under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with nuisance water under Alternative 2 would be **significant**.

11.5.7.1.7 Impact 11-7: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

The exposure of people or structures to potential substantial adverse effects involving landslides would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with landslides is considered significant.

Overall, significant impacts associated with landslides under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with landslides under Alternative 2 would be **significant**.

11.5.7.1.8 Impact 11-8: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

The potential for construction of projects that require the use of septic tanks would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with soils incapable of adequately supporting the use of septic tanks is considered significant.

Overall, significant impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 2 would be **significant**.

11.5.7.1.9 Impact 11-9: Substantial Risks to Life or Property Due to Construction of Project Facilities on High Organic Matter Soils

The potential for construction of projects on high organic matter soils would be reduced relative to the Proposed Project under Alternative 2 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with high organic matter soils is considered significant.

Overall, significant impacts associated with high organic matter soils under Alternative 2 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with high organic matter soils under Alternative 2 would be **significant**.

11.5.7.2 Mitigation Measures

Mitigation measures for impacts associated with Alternative 2 would be the same as those described for the Proposed Project in Sections 11.5.3.6.1 (Mitigation Measure 11-1) through 11.5.3.6.9 (Mitigation Measure 11-9). Because it is not known whether the mitigation measures listed above would reduce impacts to a less-than-significant level for Alternative 2, these potential impacts are considered **significant and unavoidable**.

11.5.8 Alternative 3

As described in Section 2A, Proposed Project and Alternatives, the water supply reliability projects and actions under Alternative 3 would be similar to those of the Proposed Project, although there would be less emphasis on surface water projects. Ecosystem restoration (floodplain restoration, riparian restoration, tidal marsh restoration, and floodplain expansion) would be reduced relative to the Proposed Project, and restoration on publicly owned lands, especially in Suisun Marsh and the Yolo Bypass, would be emphasized. There would be more stressor management actions (e.g., programs for water quality, water flows) and more management for nonnative invasive species. Water quality improvements would be the same as for the Proposed Project. Actions under Alternative 3 to reduce flood risk would not include setback levees or subsidence reversal but would result in greater levee modification/maintenance and dredging relative to the Proposed Project. Reservoir reoperation and rock stockpiling would be the same as for the Proposed Project, as would activities to protect and enhance the Delta as an evolving place.

11.5.8.1.1 Impact 11-1: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Rupture of a Known Earthquake Fault

The exposure of people or structures to potential substantial adverse effects involving rupture of a known earthquake fault under Alternative 3 would be similar to those that would result from the Proposed Project, except that impacts associated with surface water storage projects under this alternative would be fewer because of the reduced number of facilities constructed. Impacts associated with ecosystem restoration would be less than under the Proposed Project because restoration would be reduced.

The impacts associated with known earthquake faults resulting from projects and actions to improve water quality under Alternative 3 would be the same as the Proposed Project, as would the impacts associated with known earthquake faults resulting from actions to protect and enhance the Delta as an evolving place.

Flood risk reduction under Alternative 3 would place greater emphasis on levee modification/maintenance and dredging than under the Proposed Project, but there would be no setback levees or subsidence reversal projects. It is unclear if this shift would result in more or less levees being constructed; therefore, impacts are expected to be similar to those under the Proposed Project. Alternative 3 would produce the same types of impacts associated with Delta enhancement projects as would the Proposed Project.

Alternative 3 would reduce significant impacts relative to the Proposed Project. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential geology-related impact associated with known earthquake faults is considered significant.

Overall, significant adverse impacts associated with known earthquake faults under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with known earthquake faults under Alternative 3 would be **significant**.

11.5.8.1.2 Impact 11-2: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Due to Strong Ground Motion Associated with Seismic Shaking

The exposure of people or structures to potential substantial adverse effects involving strong ground motion associated with seismic shaking would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with strong ground motion and seismic shaking is considered significant.

Overall, significant impacts associated with strong ground motion and seismic shaking under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with strong ground motion and seismic shaking under Alternative 3 would be **significant**.

11.5.8.1.3 Impact 11-3: Projects Could Be Located on a Geologic Unit or Soil that Is Unstable, or that Would Become Unstable as a Result of the Project, and Potentially Result in Loss of Bearing Value, Lateral Spreading, Subsidence, Liquefaction, or Collapse

The potential for construction and operation of projects to occur on unstable geologic units or soils would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with unstable geologic units and soils is considered significant.

Overall, significant impacts associated with unstable geologic units and soils under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with unstable geologic units and soils under Alternative 3 would be **significant**.

11.5.8.1.4 Impact 11-4: Substantial Soil Erosion or the Loss of Topsoil

The potential for construction and operation of projects to result in substantial soil erosion or the loss of topsoil would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with substantial soil erosion or the loss of topsoil is considered significant.

Overall, significant impacts associated with the substantial soil erosion or loss of topsoil under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with substantial soil erosion or the loss of topsoil under Alternative 3 would be **significant**.

11.5.8.1.5 Impact 11-5: Construction of Projects Could Lead to Impacts Associated with the Presence of Expansive Soils

The potential for construction of projects on expansive soils would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with expansive soils is considered significant.

Overall, significant impacts associated with expansive soils under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with expansive soils under Alternative 3 would be **significant**.

11.5.8.1.6 Impact 11-6: Operation of Projects Could Result in Impacts Associated with the Occurrence of Nuisance Water in Adjacent Areas Due to Leakage

The potential for operation of projects to result in nuisance water would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed and operated are not currently known, the potential impact associated with nuisance water is considered significant.

Overall, significant impacts associated with nuisance water under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with nuisance water under Alternative 3 would be **significant**.

11.5.8.1.7 Impact 11-7: Exposure of People or Structures to Potential Substantial Adverse Effects, Including the Risk of Loss, Injury, or Death Involving Landslides

The exposure of people or structures to potential substantial adverse effects involving landslides would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with landslides is considered significant.

Overall, significant impacts associated with landslides under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with landslides under Alternative 3 would be **significant**.

11.5.8.1.8 Impact 11-8: Have Soils Incapable of Adequately Supporting the Use of Septic Tanks or Alternative Waste Water Disposal Systems Where Sewers Are Not Available for the Disposal of Waste Water

The potential for construction of projects that require the use of septic tanks would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with soils incapable of adequately supporting the use of septic tanks is considered significant.

Overall, significant impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with soils incapable of adequately supporting the use of septic tanks under Alternative 3 would be **significant**.

11.5.8.1.9 Impact 11-8: Substantial Risks to Property Due to Construction of Project Facilities on High Organic Matter Soils

The potential for construction of projects on high organic matter soils would be reduced relative to the Proposed Project under Alternative 3 for the same reasons described above for impacts associated with known earthquake faults. However, because the locations and details of projects and actions that might be constructed are not currently known, the potential impact associated with high organic matter soils is considered significant.

Overall, significant impacts associated with high organic matter soils under Alternative 3 would be **less than** under the Proposed Project.

As compared to existing conditions, the impacts associated with high organic matter soils under Alternative 3 would be **significant**.

11.5.8.2 Mitigation Measures

Mitigation measures for impacts associated with Alternative 3 would be the same as those described for the Proposed Project in Sections 11.5.3.6.1 (Mitigation Measure 11-1) through 11.5.3.6.9 (Mitigation Measure 11-9). Because it is not known whether the mitigation measures listed above would reduce impacts to a less-than-significant level for Alternative 3, these potential impacts are considered **significant and unavoidable**.

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